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TERMINATION OF FLAT CONDUCTOR CABLE
TO NASA/MSFC PLUGS

By W. Angele
Process Engineering Laboratory

October 1972



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*George C. Marshall Space Flight Center
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16. ABSTRACT

The report contains data, supplemented with artwork, on the major steps involved in terminating flat conductor cable (FCC) to MSFC's FCC plugs. Cable and shield preparation steps include material cutting, insulation stripping, and plating of exposed conductors. Methods and equipment required to terminate FCC to each of four MSFC plugs are described.

EDITOR'S NOTE

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PREFACE

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SECTION I. INTRODUCTION

PURPOSE

This document describes the manner in which flat conductor cable (FCC) is attached to four NASA/MSFC plugs, using the direct-contact method of cable termination.

This report has been designed to be sufficiently comprehensive for a clear understanding of the major steps involved; however, it is not intended for use as a manufacturing procedure and, consequently, many fabrication details have been omitted.

SCOPE

Cables, Shields, and Plugs

Flat conductor cable is the only type cable considered in this report. It is defined as cable made up of flat, parallel conductors — usually bare or plated copper — which are laminated between thin flexible plastic insulating films, or otherwise held in a flat, rectangular configuration. Flat ribbon cable, containing round wire and sometimes referred to as flat cable, is not within the document scope.

Cables, shields, and plugs commonly in use at NASA/MSFC are discussed in the following pages. Only conductor and cable sizes for which plugs are specifically designed are mentioned, although plugs can be modified slightly to enable acceptance of various conductor and cable size combinations.

Manufacturing Techniques and Equipment

Only those techniques and equipment which are used at NASA/MSFC in cable termination are described. In addition, only those fabrication methods suitable for production (rather than only lab scale operation) are discussed.

GENERAL REMARKS ON TERMINATION OF FCC

The round wire cable connector industry usually terminates FCC in a manner similar to round wire cable termination, although quicker methods are possible. Individual metal contact pieces are attached to the flat conductors by welding, crimping, brazing, or soldering. One result is that the final connector (plug and receptacle) consists of a large number of pieces. Certainly many good connectors can and are being fabricated using this conventional termination technique. However, by taking advantage of FCC's unique features, terminations of equal or higher reliability at much lower costs can be obtained.

Because conductors are arranged in one plane in FCC, all wires can be treated as a single unit during steps of termination and interconnection. NASA/MSFC uses this cable feature in its FCC direct-contact termination process, a technique designed for high reliability, low weight, and economy. Conductors are terminated in layers, rather than individually, and are used as the plug contacts, thus eliminating the need for additional contact pieces.

Conductor stripping is necessary as part of MSFC's termination process because the flat surfaces of the cable conductors are used to make and break contact. Many people think that this is a costly process, even though stripping is required for most round wire connectors. Just as round wires are stripped efficiently by the millions every day, so can flat conductors be stripped. In fact, because all conductors of a flat cable can be stripped simultaneously, operation costs should be lower than with round wire.

Wicking, often a severe problem with round wire cable terminations, and particularly with stranded wires, is a relatively insignificant problem with MSFC FCC terminations. The bond strength of flat conductors to polyimide/FEP (a major insulation system used at MSFC) can be weakened for ease of cold-blade stripping and still have sufficient adhesion to prevent wicking of moisture and to prevent excessive lengthwise shrinkage of the insulation. The wicking problem is much more severe with stranded wire, which is susceptible to flux and moisture wicking, as well as to solder wicking — a cause of undue cable stiffening.

Flexible potting can be used in all MSFC terminations. This seals and anchors the conductors, without causing excessive cable stiffening.

REPORT FORMAT

The document contains one section on cable and shield preparation and four sections on manufacturing cable-plug assemblies. Major fabrication steps are outlined in each case, supplemented with a pictorial coverage of the process.

SECTION II. CABLE AND SHIELD PREPARATION

5

CABLE HANDLING

Long runs of cable can be packaged in the device shown in Figure 1. After cable shearing, this item can be used for all manufacturing operations, including plating.

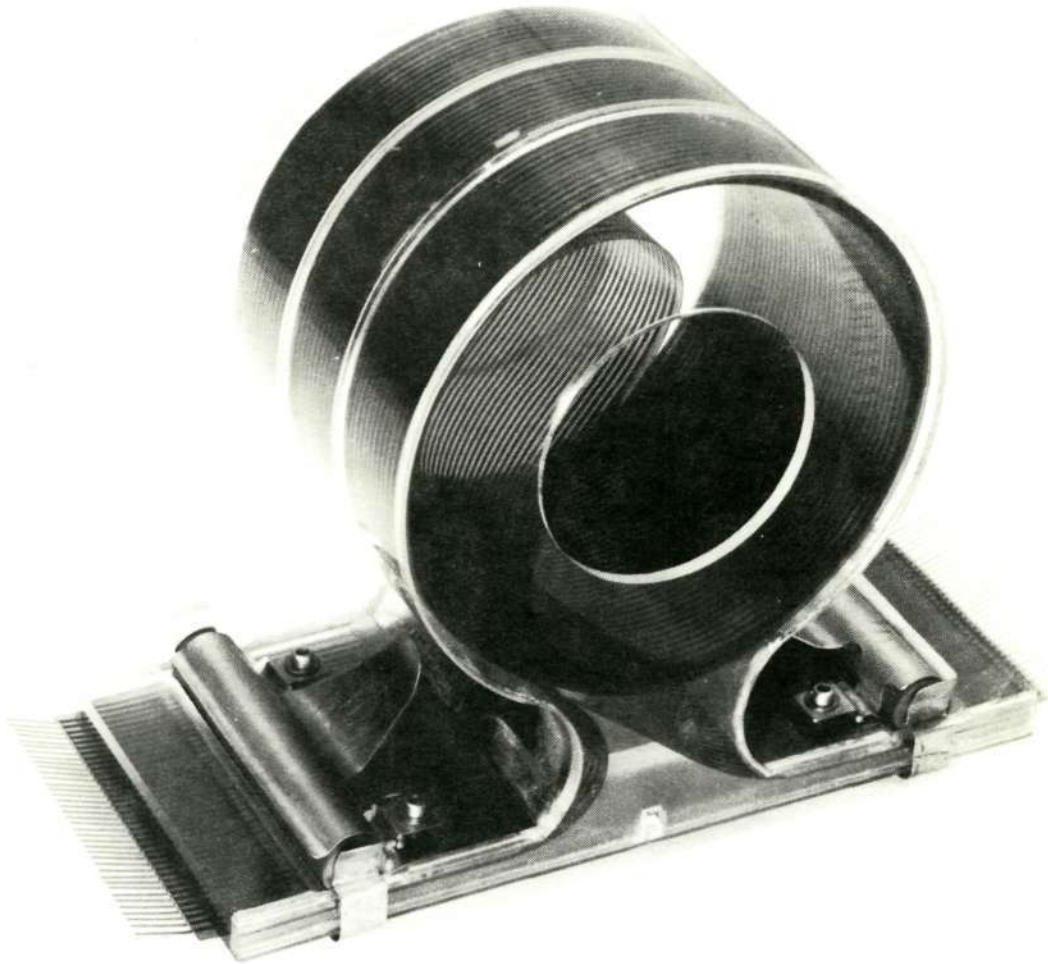


Figure 1. FCC handling device.

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CABLE SHEARING

The following procedure is used for cable shearing:

- Cable is measured, and the desired length (including strip length) is marked for cutting.
- Cable is first cut with scissors slightly beyond the mark (Fig. 2).
- Cable is finally cut at the mark, using standard sheet metal shears (Fig. 3), or any other shearing tool which has a stop for the cable edge and which makes a square cut without deforming the conductor ends.
- One or two cable lengths are prepared for each cable-to-plug termination, depending on requirements.

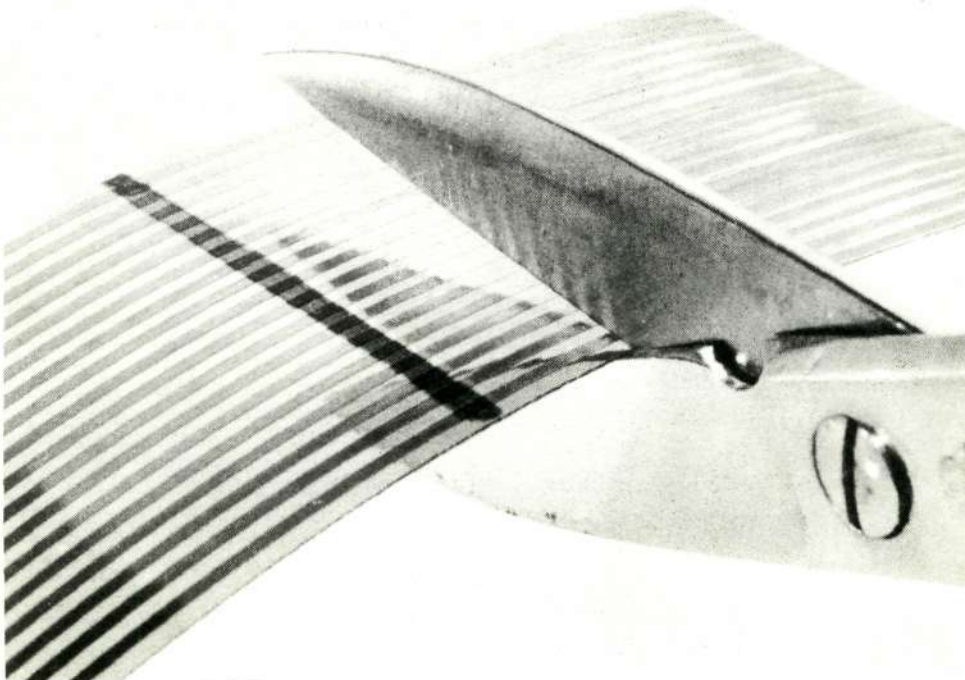


Figure 2. Making the first cable cut with scissors.

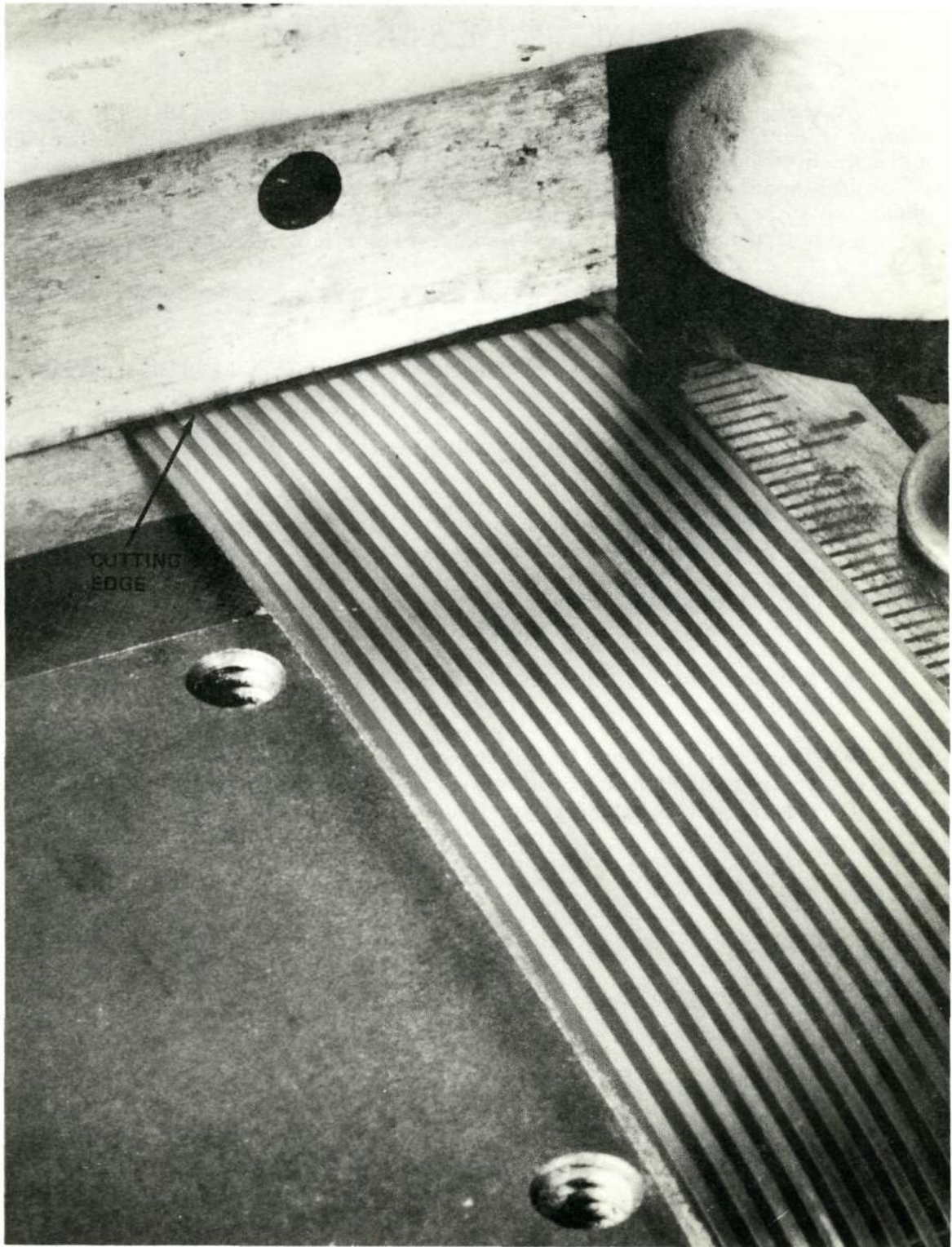


Figure 3. Making the final cable cut with sheet metal shears.

CHEMICAL STRIPPING OF UNSHIELDED POLYESTER/POLYESTER CABLE

A cable system employing polyester (Mylar) insulation bonded with polyester adhesive is one of the two major unshielded FCC systems used by NASA/MSFC. This cable is chemically stripped to expose conductors. Mechanical methods are not applicable because of the high bond strength between insulation and conductors. NASA's technique used to obtain the stripped configuration shown in Figure 4 is outlined below. The subject is covered in more detail in a comprehensive stripping report now in preparation.

- A maskant is used to define the stripping area and prevent degradation of the rest of the cable.
 - The cable end is placed in a masking fixture (Fig. 5) which assures proper mask alignment and provides a gauge for correct strip length.
 - Lead foil tape is wrapped around the cable at the desired distance from the cut end.
 - The maskant is pressed firmly in place by passing the taped cable end between two rollers of a sealing fixture (Fig. 6).
- The cable end is immersed in stripping solution (Methode DS 101 H proprietary, or equivalent) to remove insulation.
- Stripped conductors are rinsed with water, the maskant removed, and the cable wiped dry.
- Temporary protection for the stripped conductors is necessary if plating is not to be accomplished immediately. Taped-on cardboard, a modified paper clip (Fig. 7), and the handling fixture shown in Figure 1 are examples.

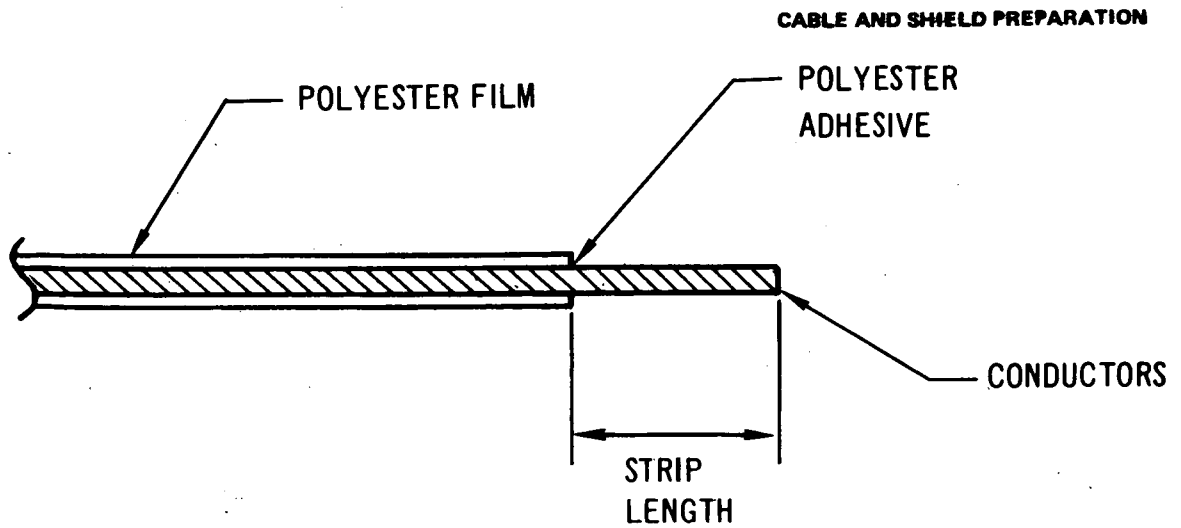


Figure 4. Stripped configuration of unshielded polyester/polyester cable.

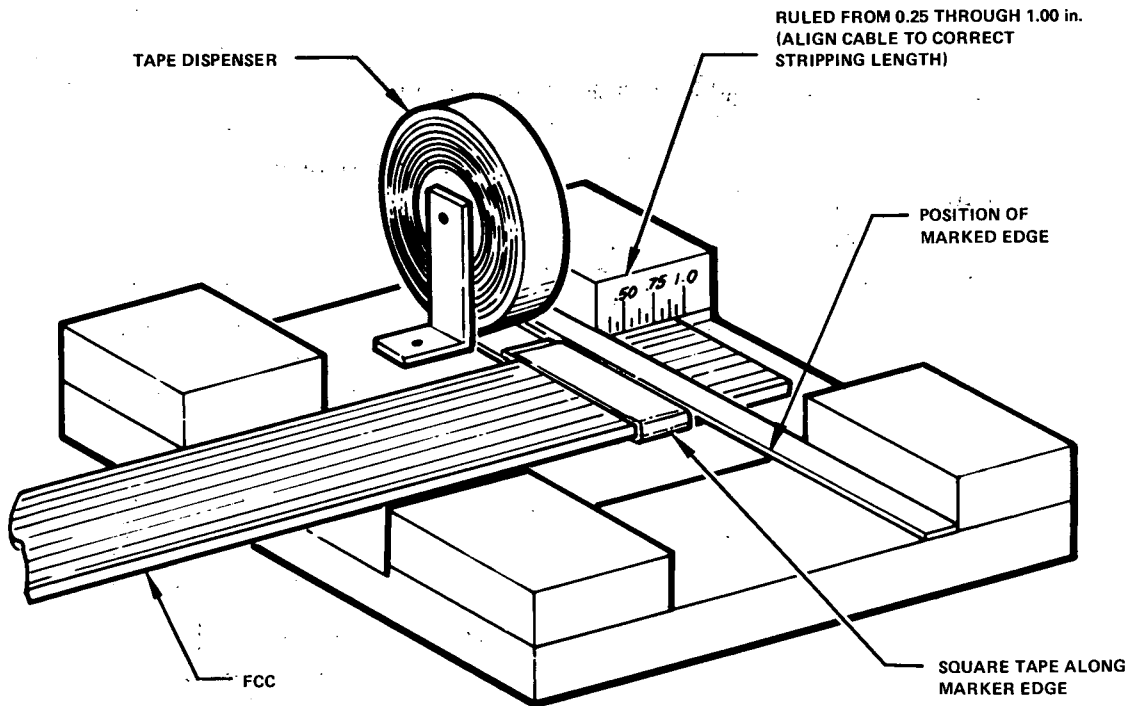


Figure 5. Masking fixture.

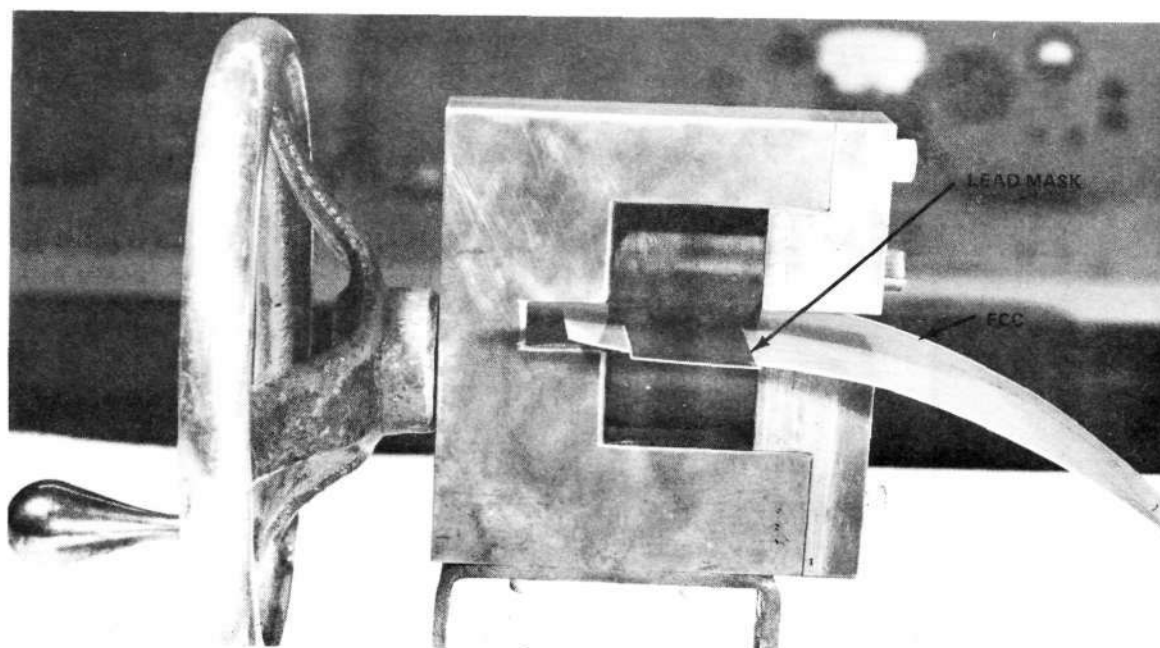


Figure 6. Mask sealing fixture.

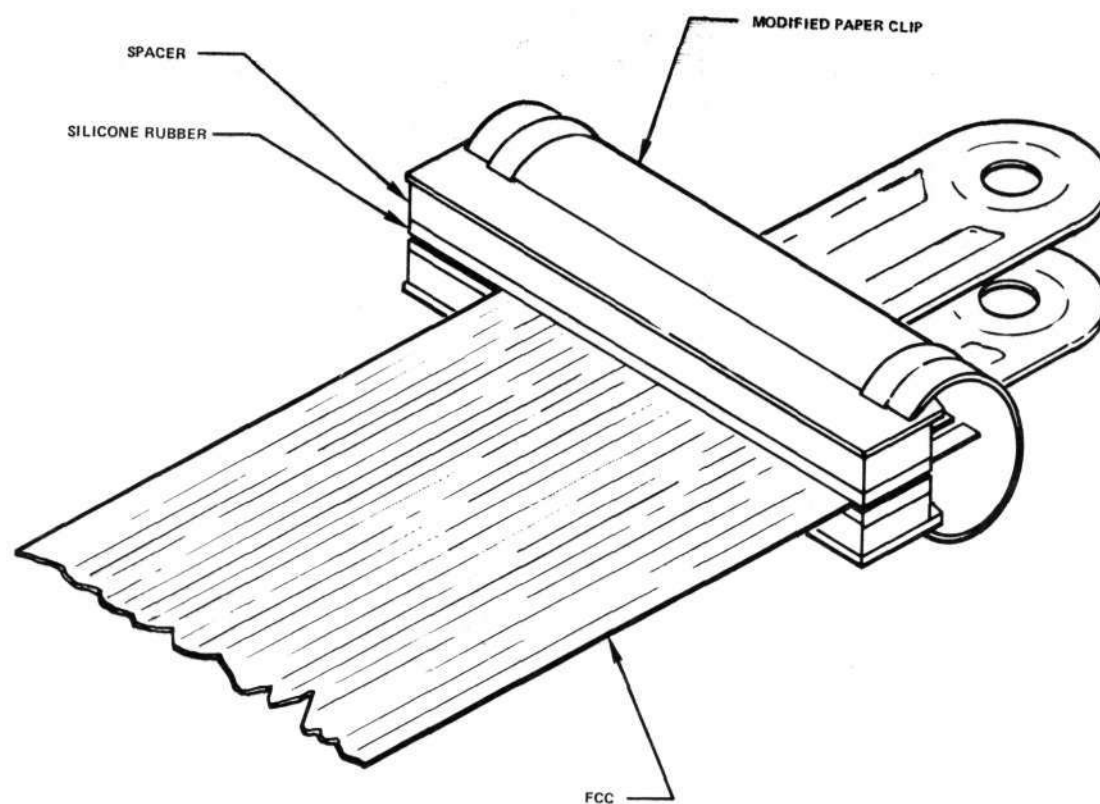


Figure 7. Conductor protecting clip.

COLD BLADE STRIPPING OF UNSHIELDED POLYIMIDE/FEP CABLE

One of the two main unshielded cable systems used by NASA/MSFC has a polyimide (Kapton) insulation bonded with an FEP Teflon adhesive. Figure 8 shows the stripped configuration of this type cable. Because FEP is impervious to all common chemicals, this cable system is stripped mechanically, using NASA's cold blade stripper (Fig. 9). The stripping part of this tool is a sharp blade which is precisely adjusted to cut the thin polyimide film and to break the FEP layer, but not to touch the cable conductors. Tool method of operation is depicted in Figure 10. The success of this stripping method is dependent upon a relatively weak bond between FEP and conductors. Major process steps are noted below. The procedure is covered in more detail in a comprehensive stripping report now in preparation.

- The cable is inserted in the stripper against a stop and clamped in place.
- An upward movement strips the insulation from the bottom of the cable.
- A return downward motion strips the insulation from the top of the cable and completes the stripping operation.
- Temporary protection for the stripped conductors is necessary if plating is not to be accomplished immediately. Figure 7 is an example.

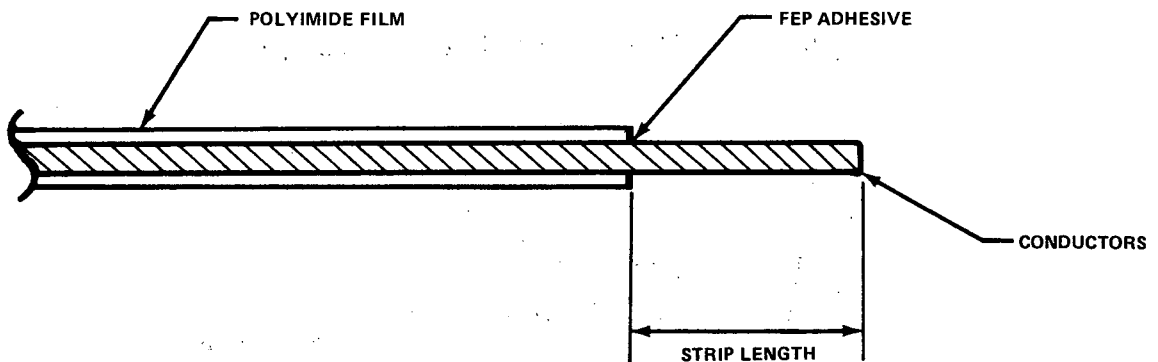


Figure 8. Stripped configuration of unshielded polyimide/FEP cable.

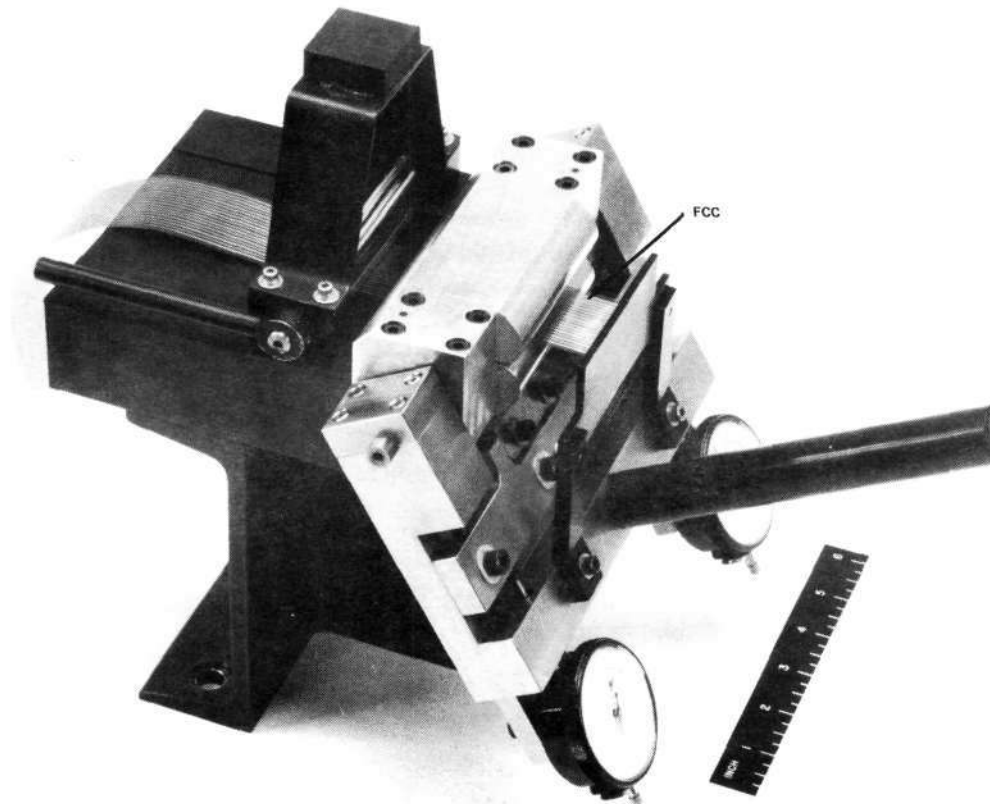


Figure 9. NASA/MSFC cold blade FCC stripper.

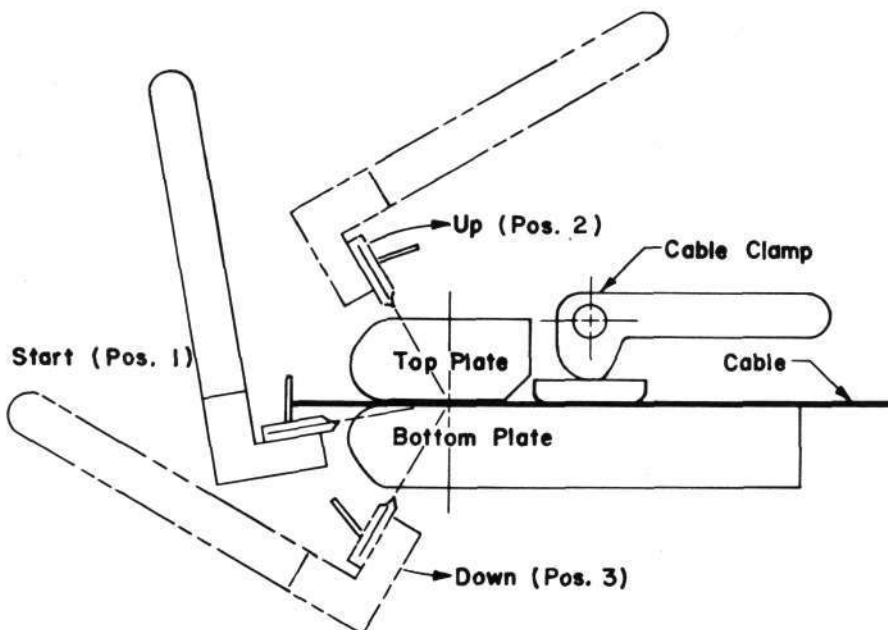


Figure 10. Stripping operations – NASA cold blade stripper.

CHEMICAL STRIPPING OF CABLE WITH BONDED SHIELDS

The stripped configuration of MSFC's FCC with bonded shields is shown in Figure 11. This type cable is available with either of two insulation systems. One system consists of a polyester (Mylar) insulation bonded with a polyester adhesive, and the other consists of a polyimide (Kapton) insulation bonded with a high temperature polyester adhesive. In all cases two copper-foil shields are attached to the two outer conductors for the full length of the cable. The basic steps of masking, chemical stripping, temporary protection of the stripped conductors, and the equipment used are the same as described and depicted earlier under "Chemical Stripping of Unshielded Polyester/Polyester Cable." Major steps are noted below. The method is described in more detail in a comprehensive stripping report now in preparation.

- A maskant (lead foil tape) is used to define the area of the first cable layers to be stripped, and to prevent degradation of the rest of the cable (Figs. 5 and 6).
- The two outer layers of insulation and the plastic fillers (see Figure 11) are chemically stripped. Process apparatus (handling equipment and tank with solution agitator) is basically the same as shown later in Figure 13 under "Conductor Plating." Although only one cable is shown, the process principle could be used to enable stripping of several cables at one time. If the outer insulation/plastic filler system is polyester bonded with a polyester adhesive, then Methode DS 101 H (proprietary) or the equivalent is used as the etchant. If the system is polyimide bonded with a polyester adhesive, London Chemical Co. Wire Stripper #PT-S-ML (proprietary) or the equivalent is used as the etchant. The cable end is cleaned.
- The two copper foils are chemically stripped, using ferric chloride, and the cable end is cleaned.
- The maskant is removed.
- A second maskant is applied, in front of the area previously masked (toward conductor ends), to define the new strip area. The stepped configuration of the cable end layers, which results from the use of two maskants, prevents electrical interference between shields and signal conductors.
- The layers of insulation on either side of the signal conductors are chemically stripped with hot etchant, and the cable end cleaned. The etchants described above are used, depending on the type insulation/adhesive system.
- Temporary protection for the stripped conductors is necessary if plating is not to be accomplished immediately. Figure 7 is an example.

CABLE AND SHIELD PREPARATION

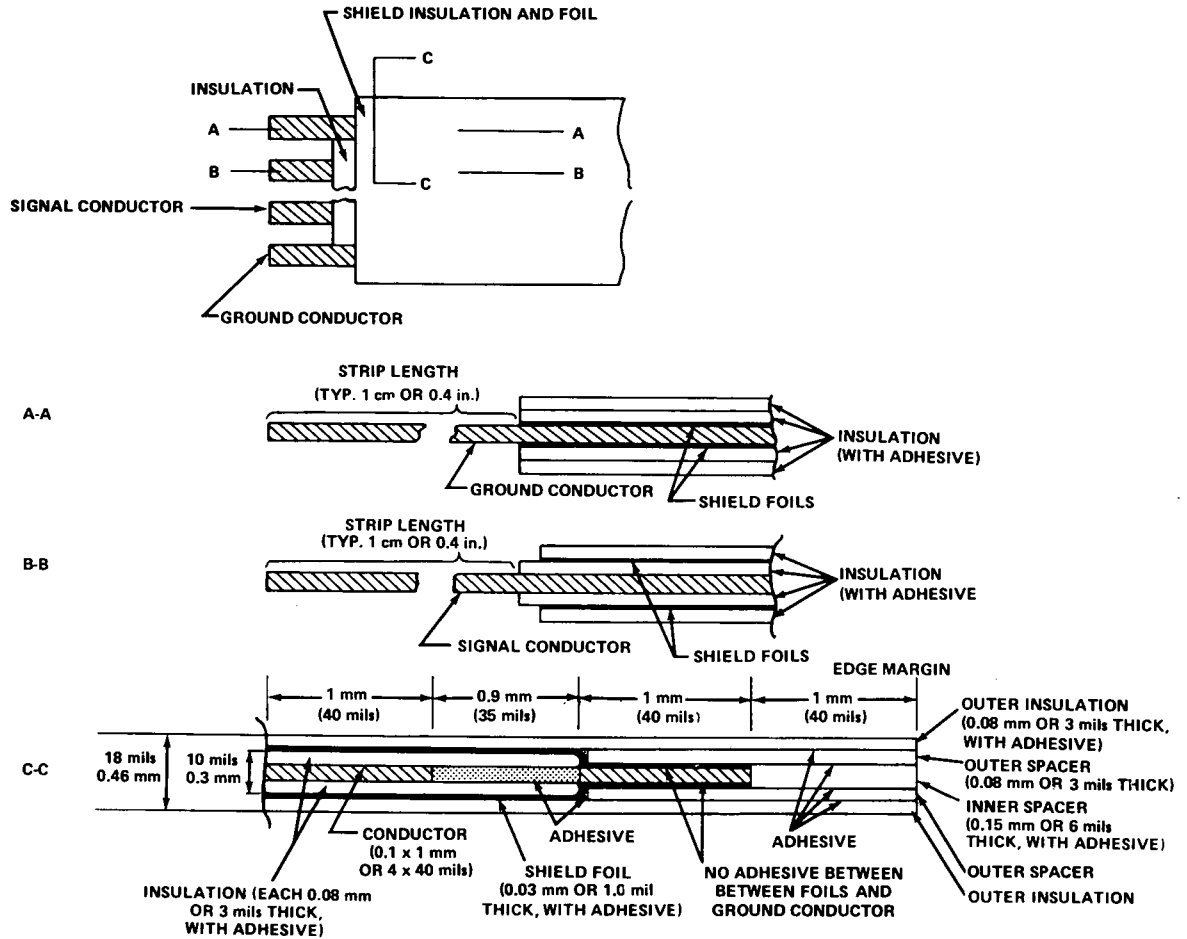


Figure 11. Stripped configuration of FCC with bonded shields.

PREPARATION OF CABLE WITH LOOSE SHIELDS

Attaching loose shields to a standard cable results in another type of MSFC shielded cable, shown in Figure 12. In this case, cable and shields are prepared separately, using a combination of methods previously discussed, and are then joined at the ends. The shield consists of a thin copper foil insulated with polyimide (Kapton)/high temperature polyester adhesive. After the shield end is stripped, a copper solder tab is applied to the end, providing reinforcement, and thus preventing tearing of the thin foil. The cable can be either of the three standard types discussed earlier: polyester (Mylar)/polyester, polyimide (Kapton)/high temperature polyester, or polyimide (Kapton)/FEP. Fabrication of the basic cable with two loose shield assemblies is described below. The subject is described in more detail in a comprehensive stripping report now in preparation.

- The ends of two loose shields are masked and one side of each is chemically stripped with a hot etchant (London Chemical Co. Wire Stripper #PT-S-ML proprietary, or equivalent). All procedure steps and basic equipment noted in "Chemical Stripping of Unshielded Polyester/Polyester Cable" are applicable here.
- A solder tab is soldered to the end of each prepared loose shield.
- The cable ends are masked and stripped, as described in earlier sections.
 - If the insulation system is polyester/polyester or polyimide/polyester, cable ends are stripped chemically.
 - If the insulation system is polyimide/FEP, cable ends are stripped mechanically.
- One shield-tab assembly is attached to the cable. This is accomplished by soldering a tab extension to each cable ground conductor. The second shield-tab assembly is attached to the underside of the cable in the same manner.
- Temporary protection for the stripped conductors is necessary if plating is not to be accomplished immediately. Figure 7 is an example.

CABLE AND SHIELD PREPARATION

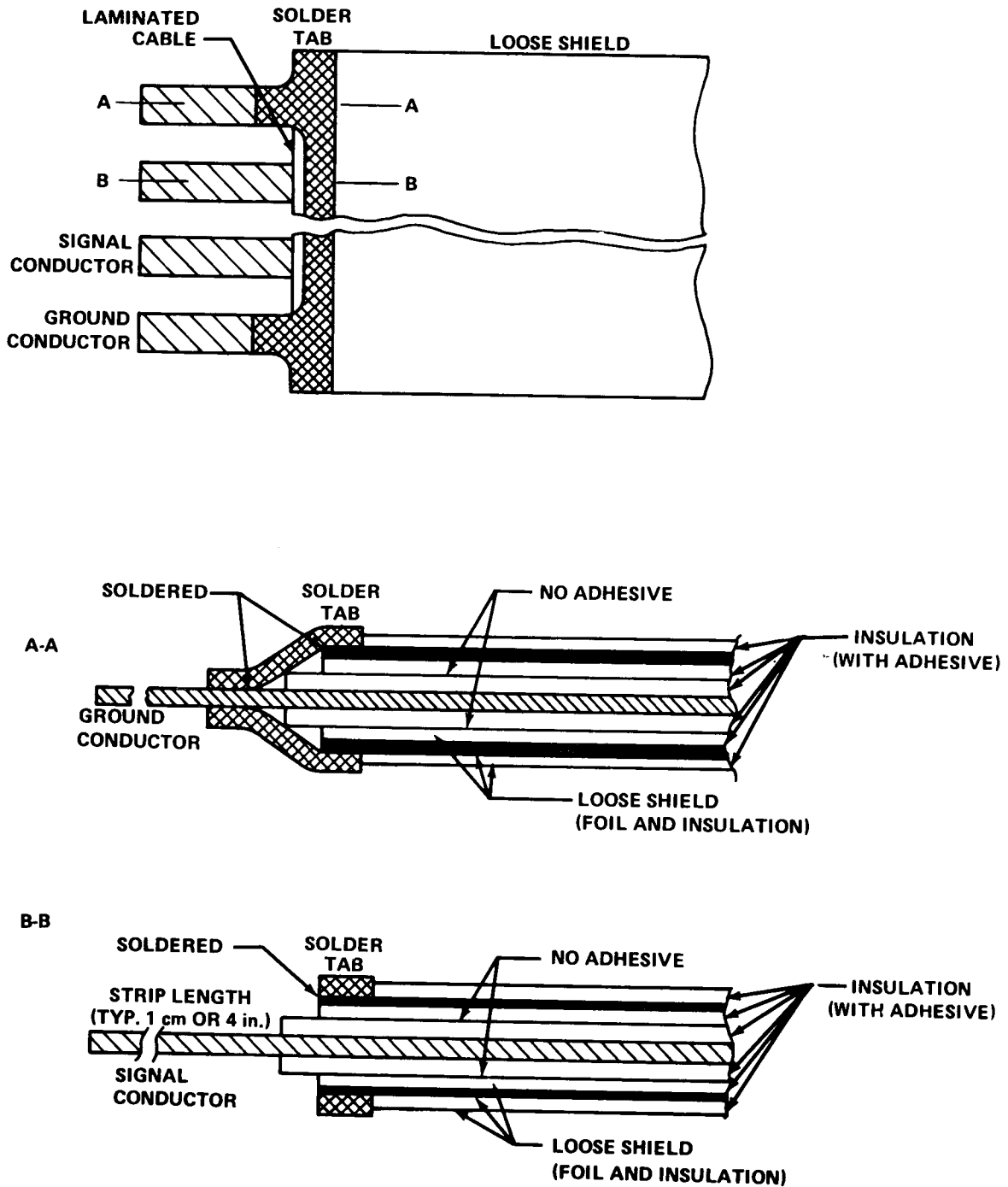


Figure 12. FCC with loose shields, prepared for termination to a plug.

CONDUCTOR PLATING

After lengths of cable have been measured and cut, and the cable ends stripped of insulation, the exposed conductors are usually plated prior to termination to a plug. The cables used by NASA/MSFC normally contain either bare copper conductors or nickel-plated copper conductors. If already nickel-plated, the stripped conductors are given only a gold film. If bare, gold over nickel is applied.

Copper conductors are plated with electrodeposited gold-over-nickel to provide (a) good surface conductance, (b) prevention of copper corrosion, and (c) long wear. The nickel plating serves as a corrosion barrier and as a receiving surface for the gold plating, which provides excellent surface conductivity, resistance to corrosion, and resistance to contact wear.

- The cable is mounted in a plating rack, to which a jumper wire from the cathode has been attached. The plating assembly is shown in Figure 13. Although only one cable is shown, the process principle could be used to enable plating of several cables at once. After conductor cleaning, and with the required cleaning between steps, the following are performed.
- Nickel plating, Type VII, Class 2, per FED-SPEC-QQ-N-290 is applied to the stripped conductors. A minimum of 0.0025 mm (0.0001 in.) is plated.
- Gold plating, Type II, Class 2, per MIL-G-45204 is applied to the nickel-plated conductors. A minimum of 0.0025 mm (0.0001 in.) is applied.
- Temporary protection for the plated conductors may be necessary (Fig. 7).

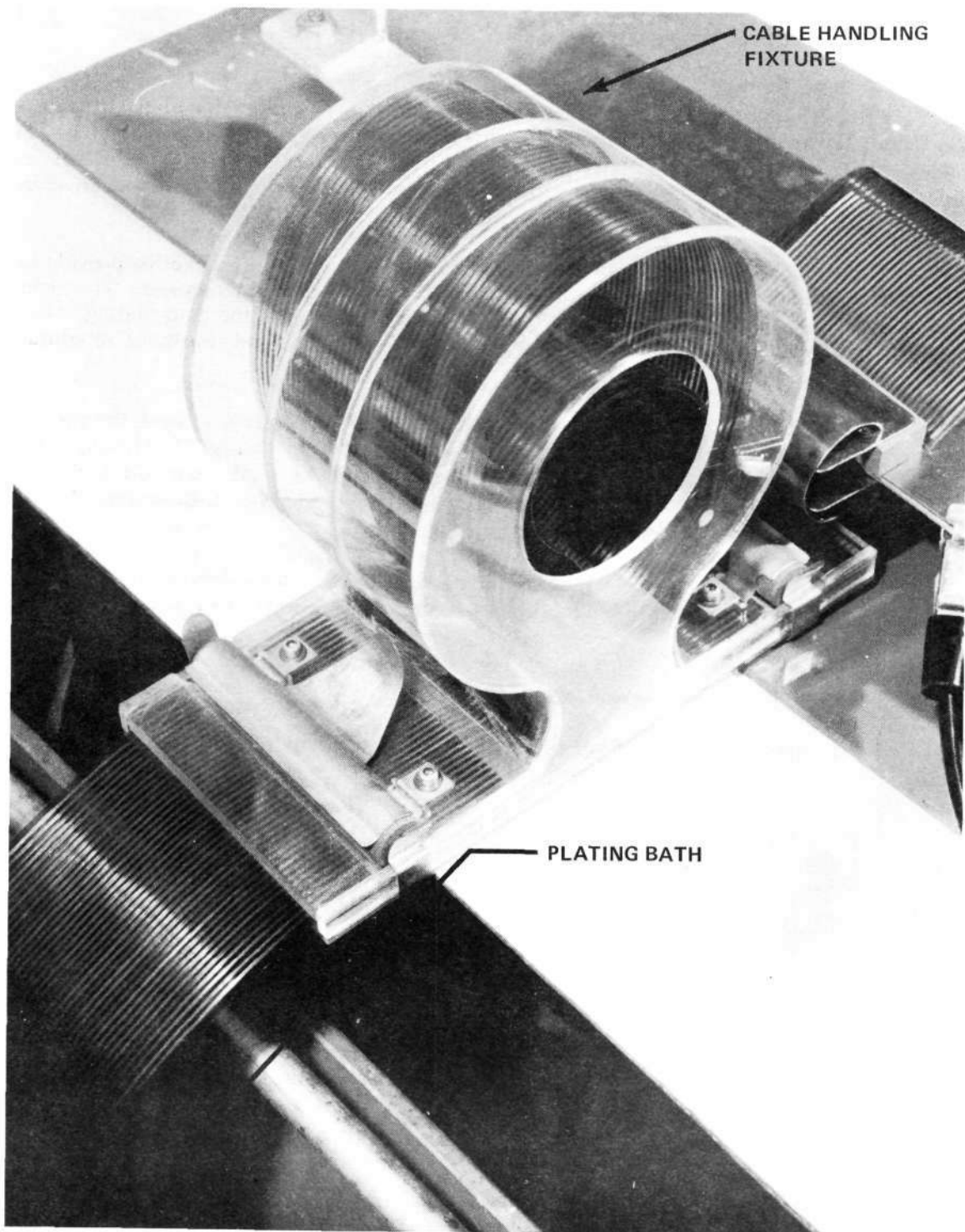


Figure 13. Conductor plating assembly.

**SECTION III. TERMINATION OF FCC TO RECTANGULAR
MOLDED-ON PLUG (50M72604)**

21

PLUG DESCRIPTION

The rectangular plug (50M72604) which is molded onto the FCC is one of four FCC plugs developed and used by NASA/MSFC. Designed to meet or exceed MIL-C-55544, this plug mates with different receptacles (50M72600, 95M20000, 50M72646) for FCC to flat (FCC or PC board) and FCC to round wire connections. Figure 14 is a conceptual drawing of the cable termination process and Figure 15 is a sectional drawing of the actual plug.

SIZES

Five sizes of plugs are available for cable ranging from 2.5 to 7.6 cm (1 to 3 in.) in width. Plugs will accommodate two flat conductor cables, containing a total of from 24 to 76 conductor-contacts. These contacts measure 1 x 0.1 mm (0.040 x 0.004 in.) and are spaced on 1.9 mm (0.075 in.) centers.

OPERATING CONDITIONS

In accordance with MIL-C-55544, the plug (when mated) is designed for operation at 300 volts rms and 3 amperes of current per contact. The mated plug-receptacle assembly has a wear-life of at least 500 insertions. Plugs are capable of continuous operation over a temperature range of -65 to +125°C (-85 to 257°F).

CABLE AND SHIELD TERMINATION

Cables are terminated to the plug by stripping cable ends, plating the conductors (if required), and folding the conductors in the plug so as to form contact surfaces. By using conductors as plug contacts, the need for additional contact pins is eliminated, and overall reliability is increased. Bonded-on and loose shields are terminated to the two outer conductors of each cable. These ground conductors are formed into contacts like other conductors.

ASSEMBLY TIME

Based on an assembly study in which FCC was terminated to twenty 3.8 cm (1.5 in.) plugs using only hand tools, total assembly time required to terminate two unshielded cables to one plug is about 10 man-minutes. This includes all plug assembly steps beginning with cutting of the two cables. If stripped conductors do not need to be plated, assembly time is reduced to 7 man-minutes. On a mass production level, total assembly time would be further reduced.

PLUG PARTS

The plug, in addition to potting, consists of the following:

1. Window piece, through which the uninsulated cable conductors are threaded;
2. Conductor spacer, which separates conductors of one cable from the other and anchors the conductor-contacts;
3. Insulator to hold the conductor-contacts in place;
4. Molded portion that integrates all components and contains polarity keys; and
5. Peripheral environmental seal.

SECTION DESCRIPTION

The remainder of this section is devoted to a step-by-step presentation of the method of terminating cables and shields to a rectangular molded-on plug, and the assembly of the plug.

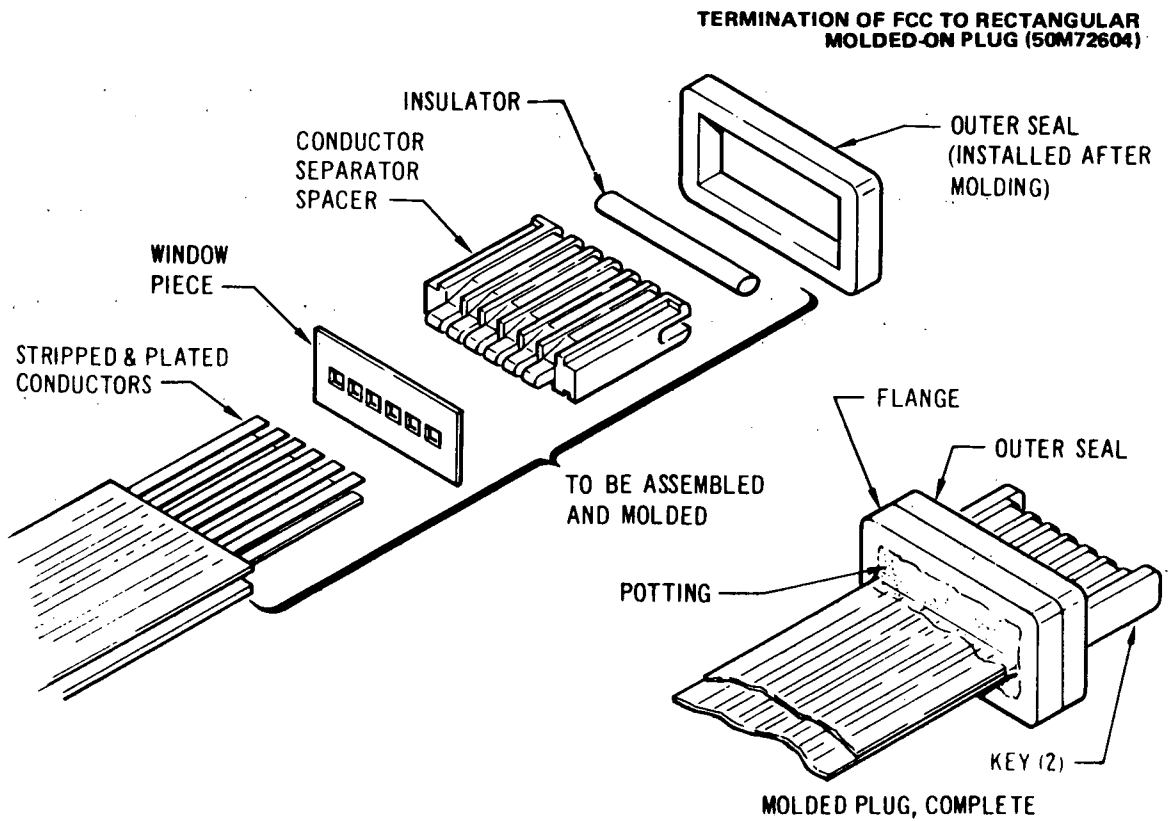


Figure 14. Conceptual drawing of rectangular molded-on plug, exploded view.

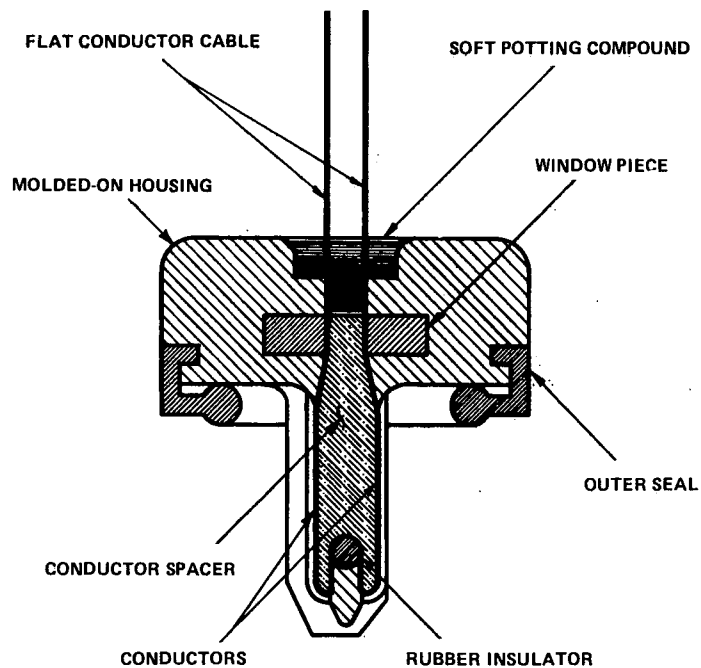


Figure 15. Rectangular molded-on plug (sectional).

ASSEMBLY OF WINDOW PIECE AND CONDUCTOR SPACER

The following steps are followed to assemble the window piece and conductor spacer.

- Conductors, stripped to a length of 1.2 cm (0.47 in.), of the two cables are threaded through the windows of the window piece (Fig. 16).
- The window piece assembly is installed in the seating fixture (Fig. 17). This tool is used for positioning and seating the window piece and conductor spacer.
- The window piece is seated (aligned with respect to the cables). Figure 18 shows the window piece being seated.
- Conductors of one cable are separated from those of the other (Fig. 19).
- The conductor spacer is inserted in the windows of the window piece and seated (Fig. 20).
- Conductors of one cable are combed into side grooves of the spacer (Fig. 21). This is repeated for the other cable.
- The assembly is removed from the seating tool.

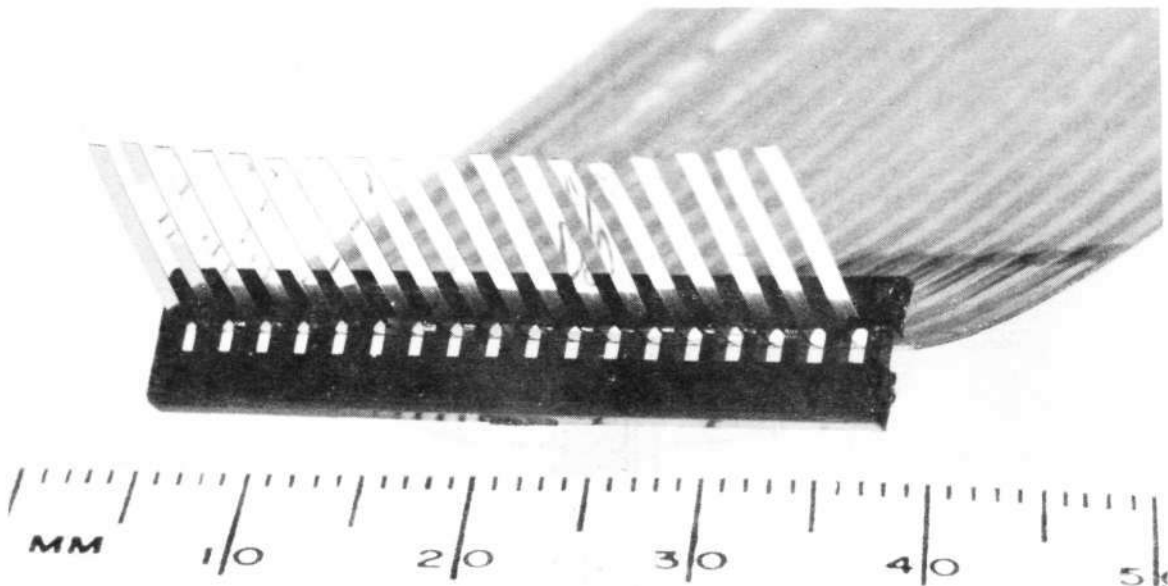


Figure 16. Threading conductors through windows of the window piece (only one cable shown).

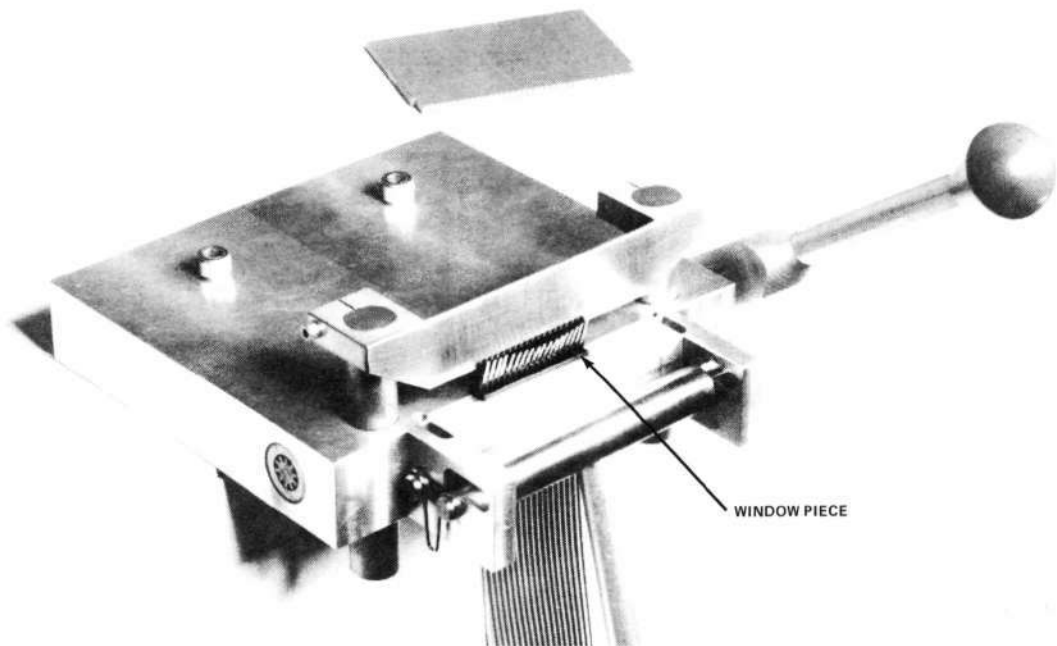


Figure 17. Seating fixture.

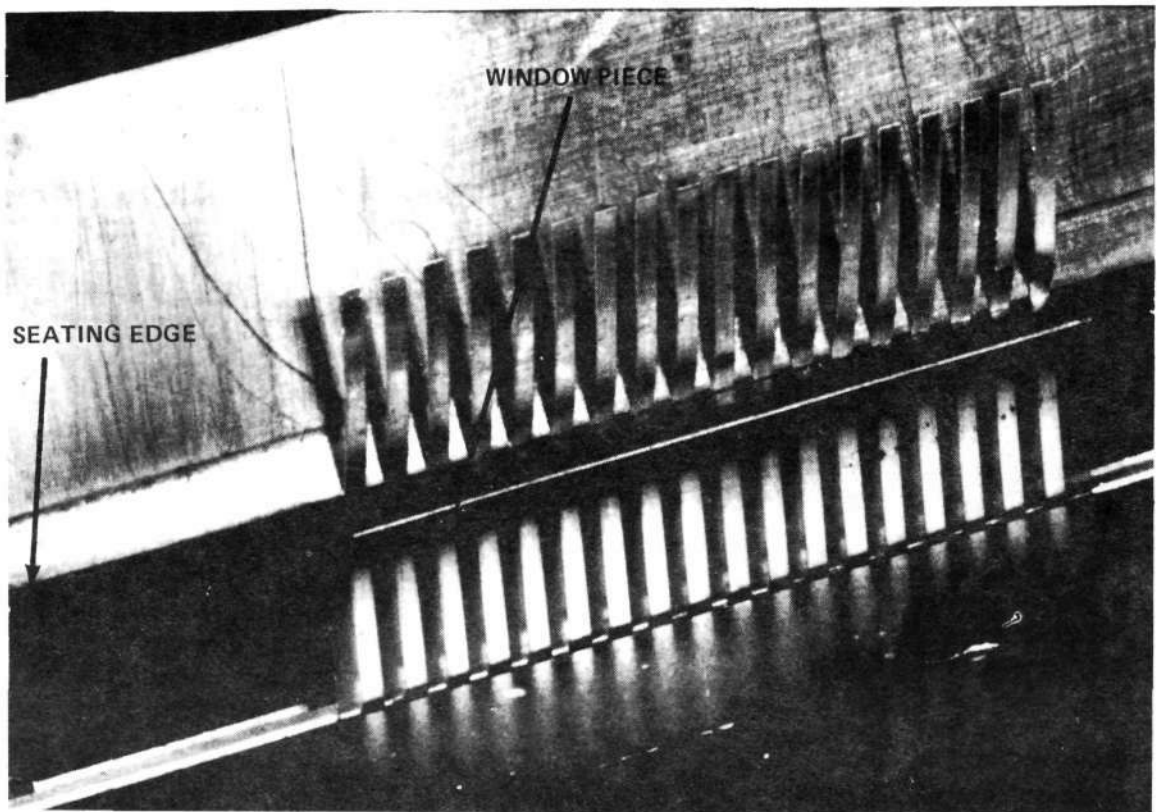


Figure 18. Seating the window piece.

TERMINATION OF FCC TO RECTANGULAR
MOLED-ON PLUG (50M72604)

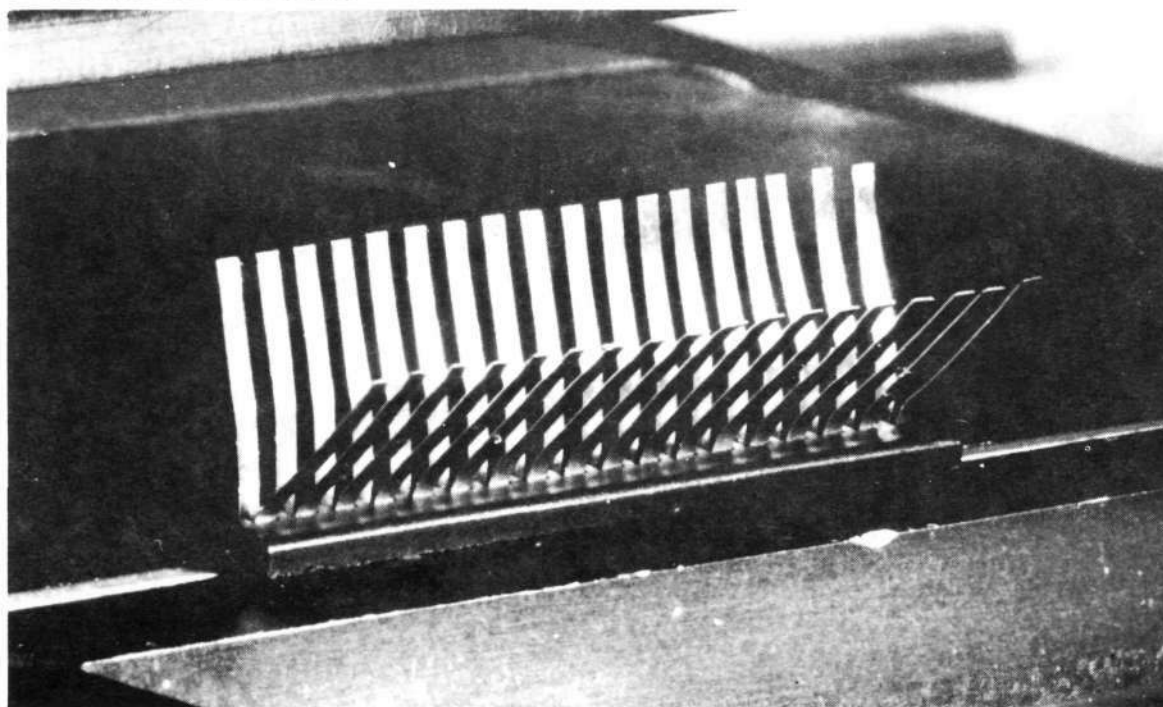


Figure 19. Separating conductors of the two cables.

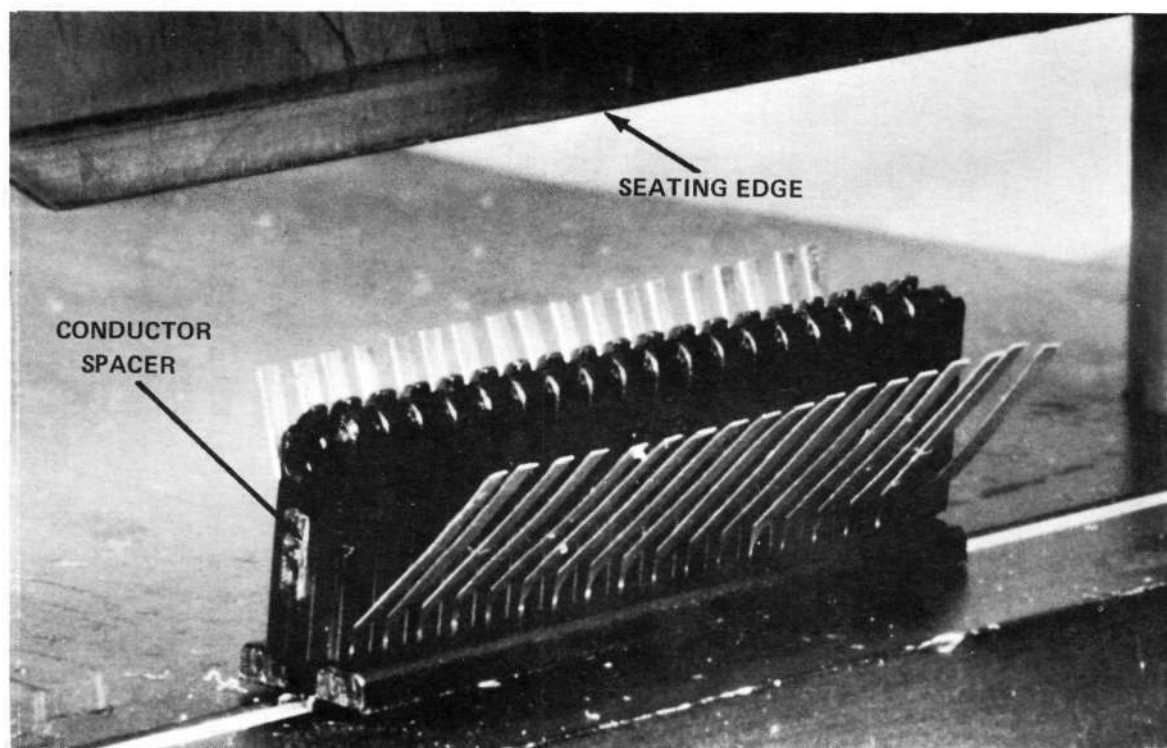


Figure 20. Conductor spacer inserted in the window piece.

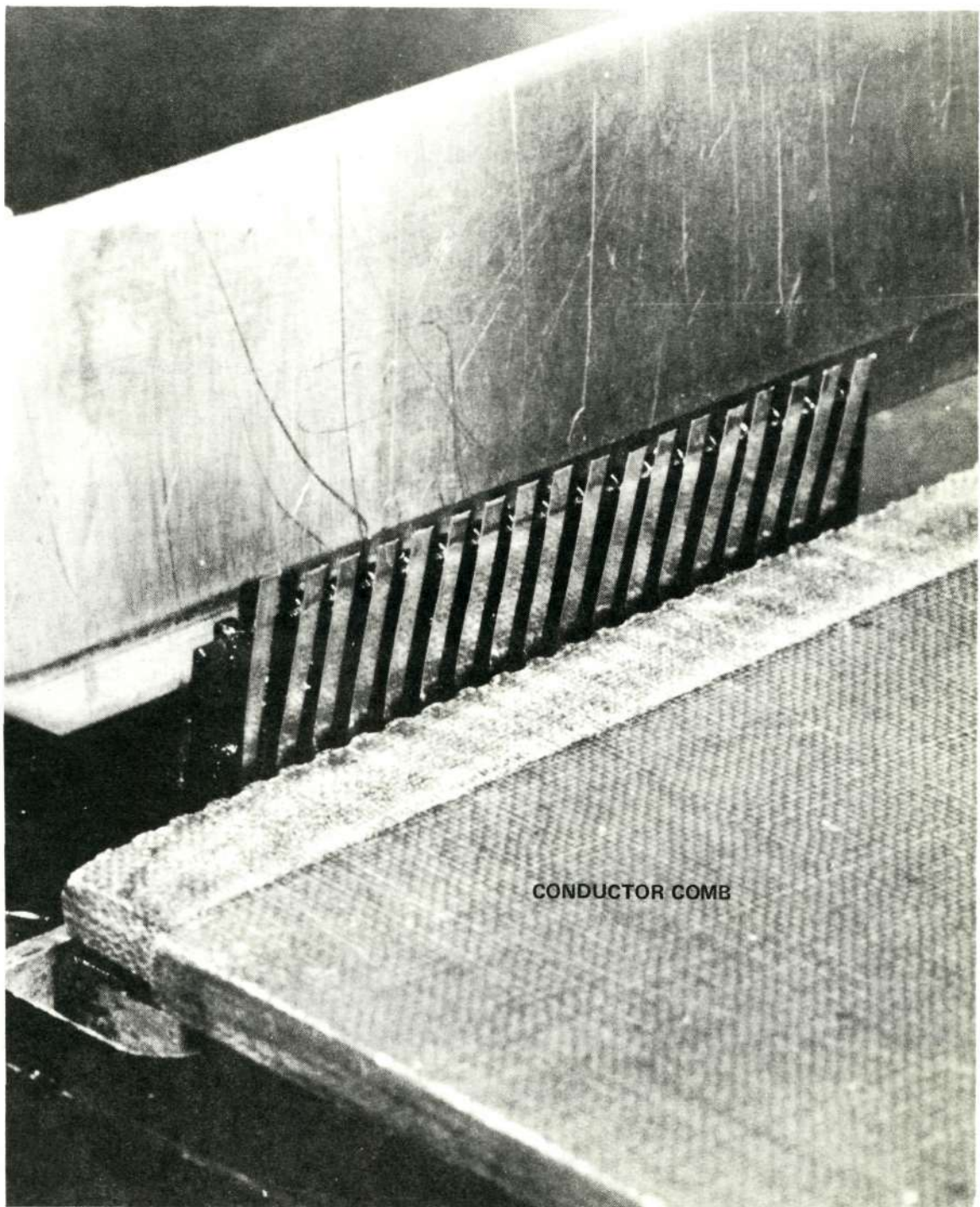


Figure 21. Combing conductors into the spacer side grooves.

FOLDING THE CONDUCTORS AND INSTALLING THE INSULATOR

The following steps are used for this procedure.

- The seated assembly is inserted through the front opening of the folding tool, positioned against the stop, and clamped. Figure 22 is a closeup of the folding tool.
- Conductors of one cable are bent at a right angle and then into the insulator groove. The operations are repeated for the other cable.
- The assembly is removed from the folding tool.
- An insulator is pressed into the spacer groove to retain the conductors, and is trimmed (Figs. 23 and 24). The insulator is covered and held in place permanently by the molded-on portion formed in the next step.

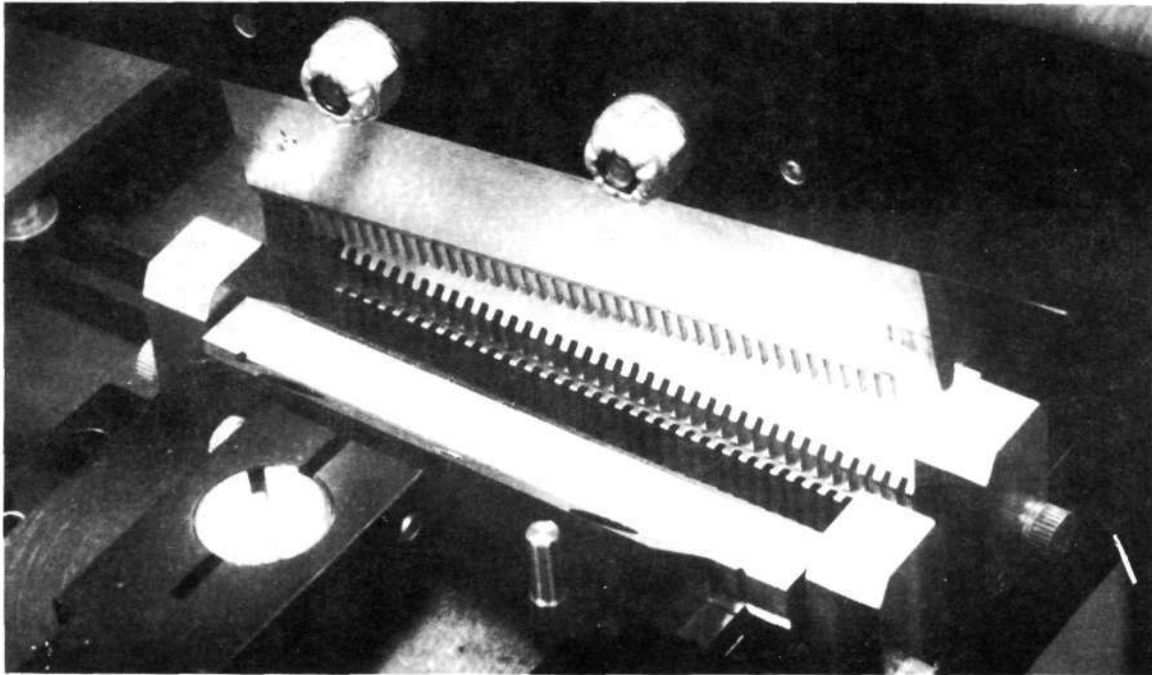


Figure 22. Closeup of folding tool.

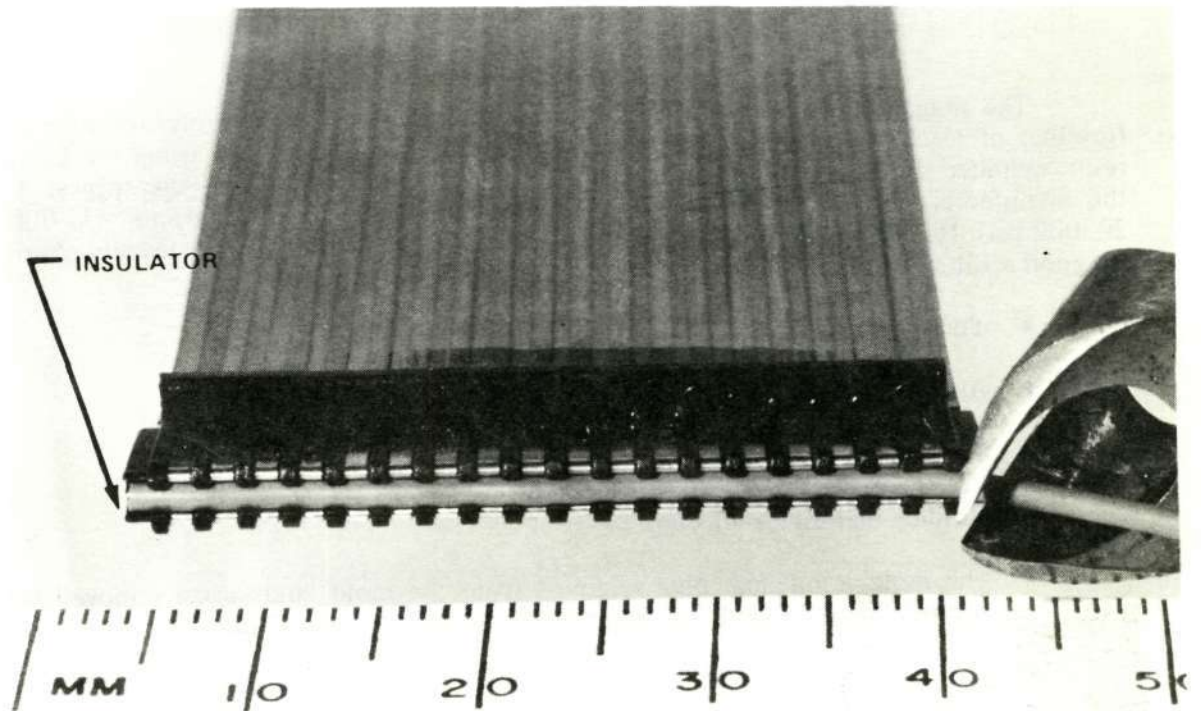


Figure 23. Trimming the insulator.

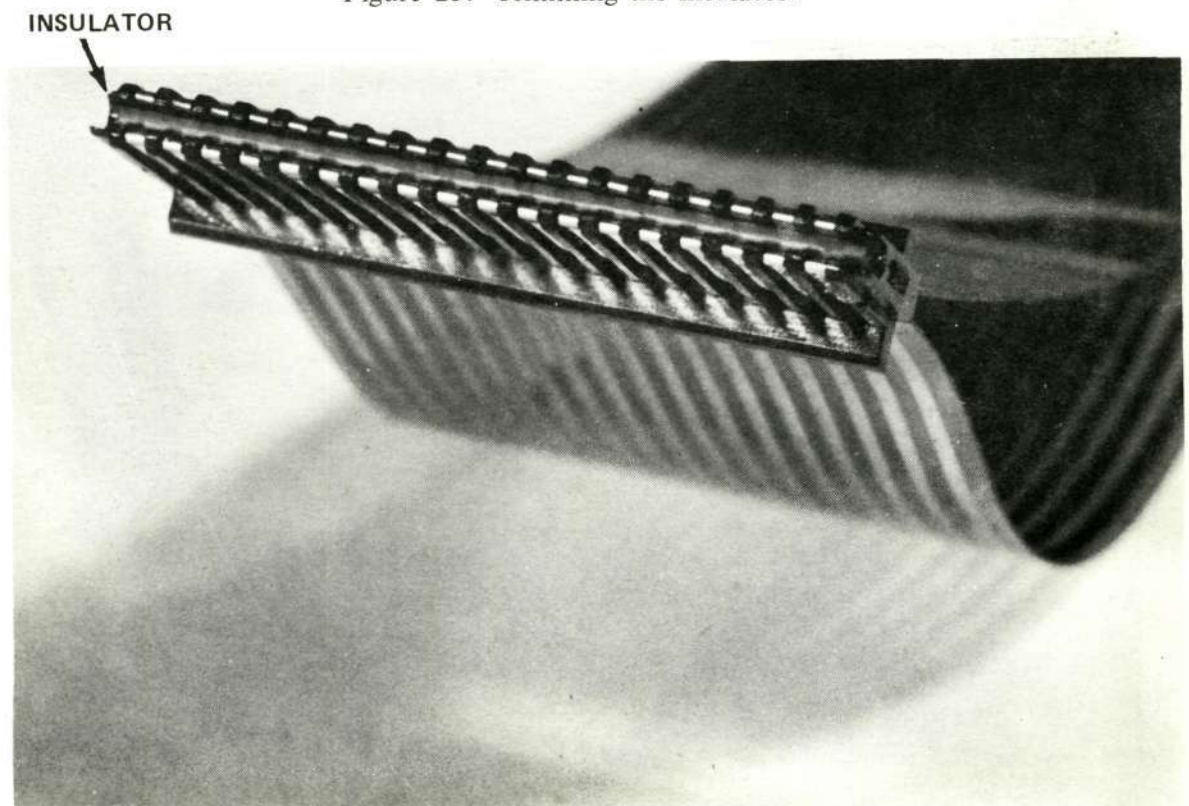


Figure 24. Installed and trimmed insulator.

INJECTION MOLDING OF THE PLUG BODY

The plug body is formed by injection molding, using Lexan[®] polycarbonate resin (product of General Electric), or another suitable thermoplastic. When using the Lexan[®] resin, cylinder and nozzle temperatures of 274 to 316°C (525 to 600°F) are suggested by the manufacturer. Typical of injection pressures are 1050 to 1400 kgf/cm² (15 000 to 20 000 psi). Heated molds in the range of 77 to 93°C (170 to 200°F) are usually required for good results. Major steps in plug body formation are listed below.

- The spacer is inserted between cables.
- Assembled parts are placed in the lower mold half (Fig. 25).
- The top of the mold is lowered onto the bottom half.
- Molding material is injected.
- The mold is opened, plug removed from the mold, and spacer removed from between cables. Plug body and mold sprue are shown in Figure 26.
- Trimming of the mold sprue from the plug body is performed using the sprue cutoff tool (Fig. 27).

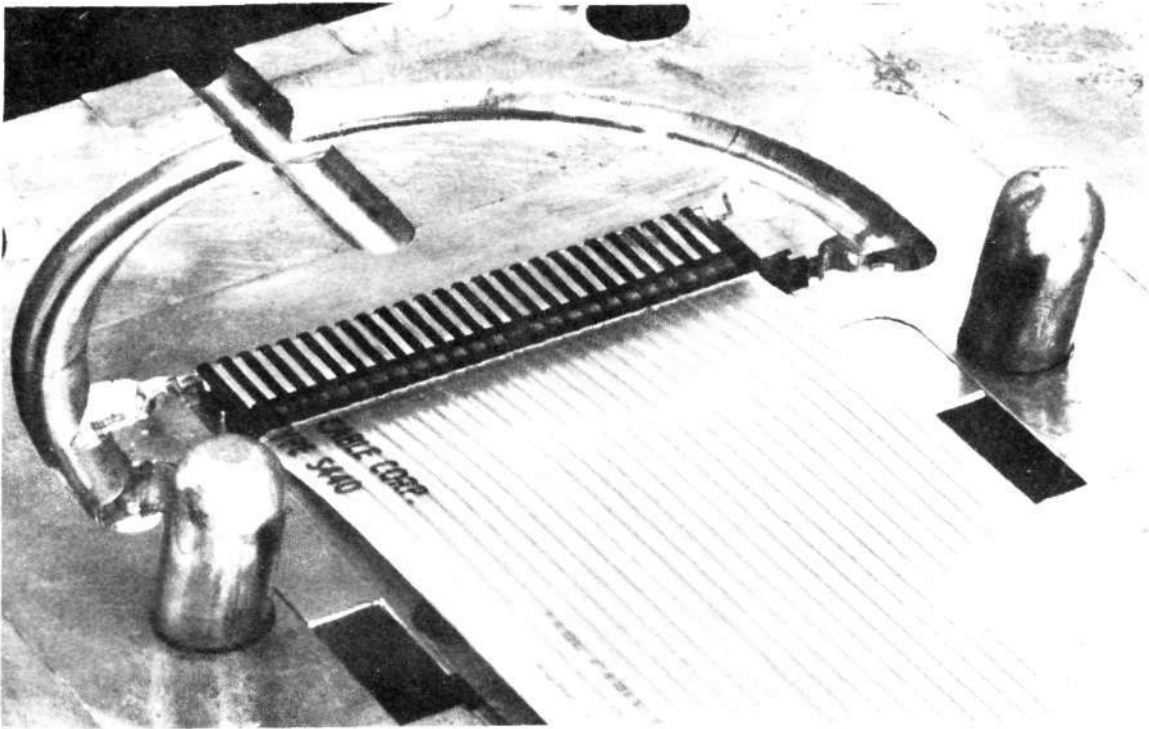


Figure 25. Partial plug in lower mold half.

TERMINATION OF FCC TO RECTANGULAR
MOLDED-ON PLUG (50M72604)

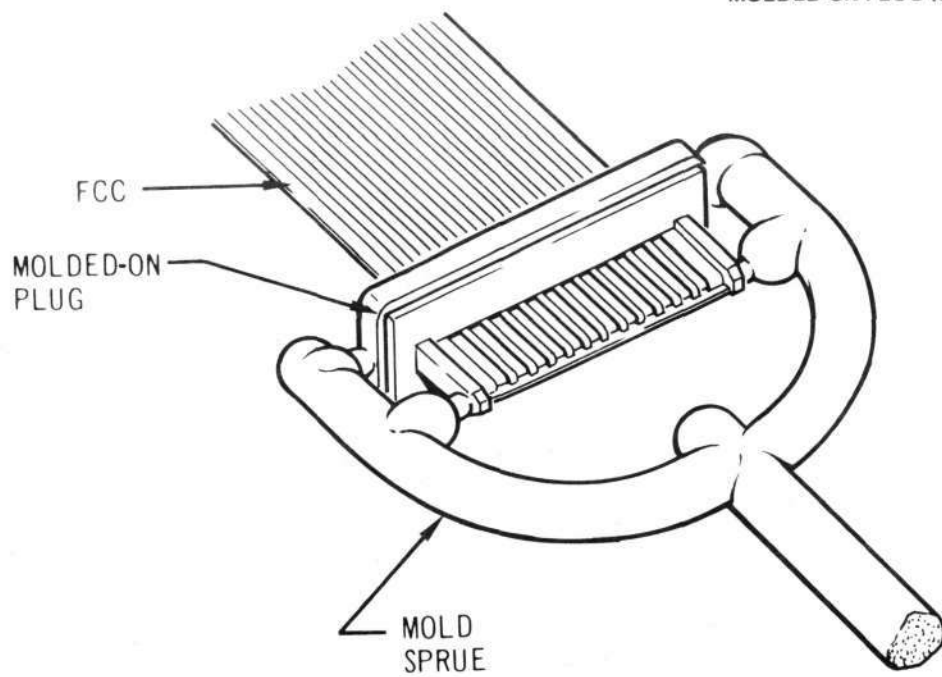


Figure 26. Molded-on plug with sprue intact.

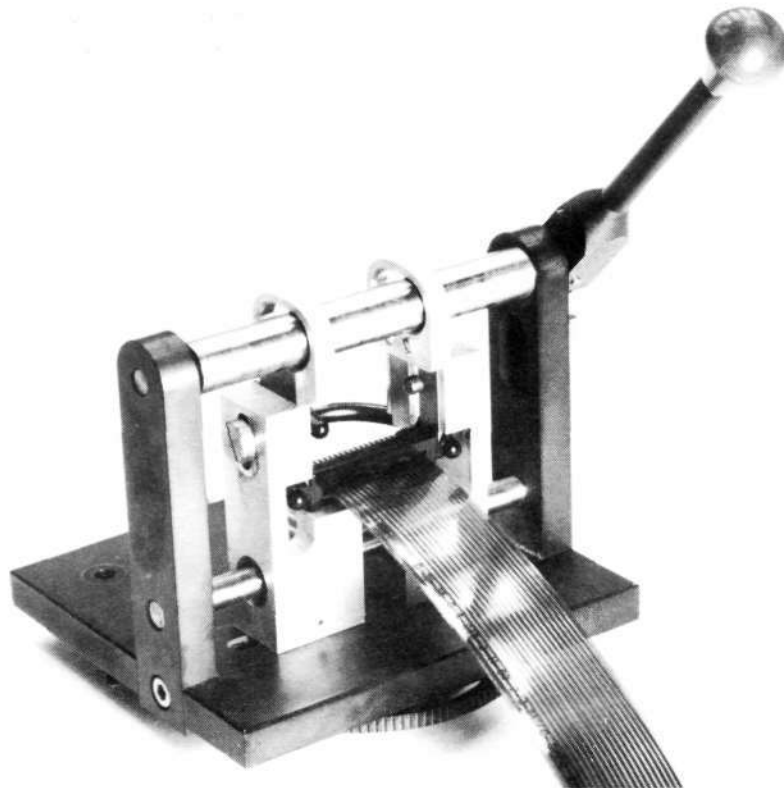


Figure 27. Sprue cutoff tool.

PLUG FINISHING

The following procedure is used to finish the plug.

- Polyurethane potting compound PRC 1535, or equivalent, is applied around and between the cables at the rear of the plug. This procedure is shown in Figure 28. Potting is then cured at 60°C (140°F) for 8 hours.
- The seal is pressed in the groove around the plug body, as shown in Figure 29.

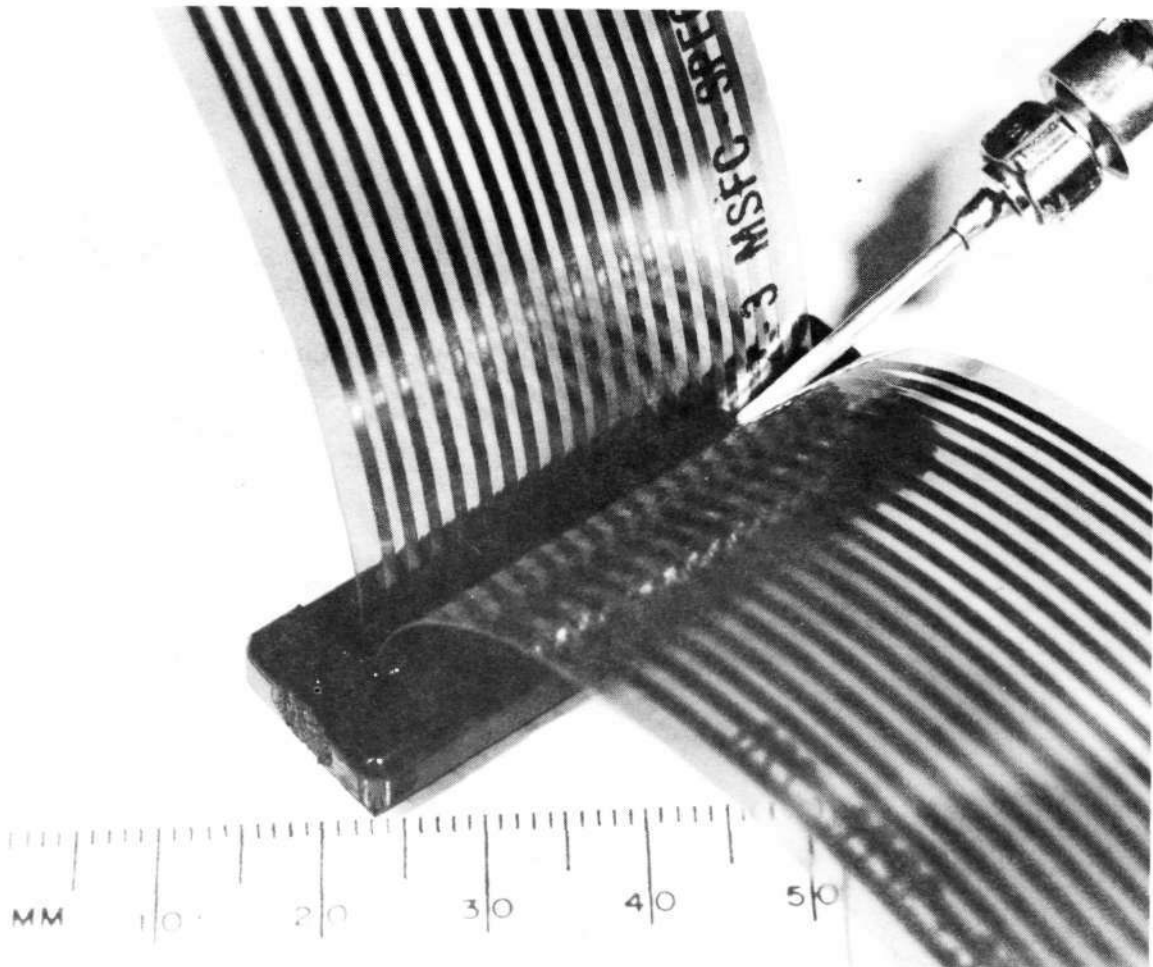


Figure 28. Potting the plug back.

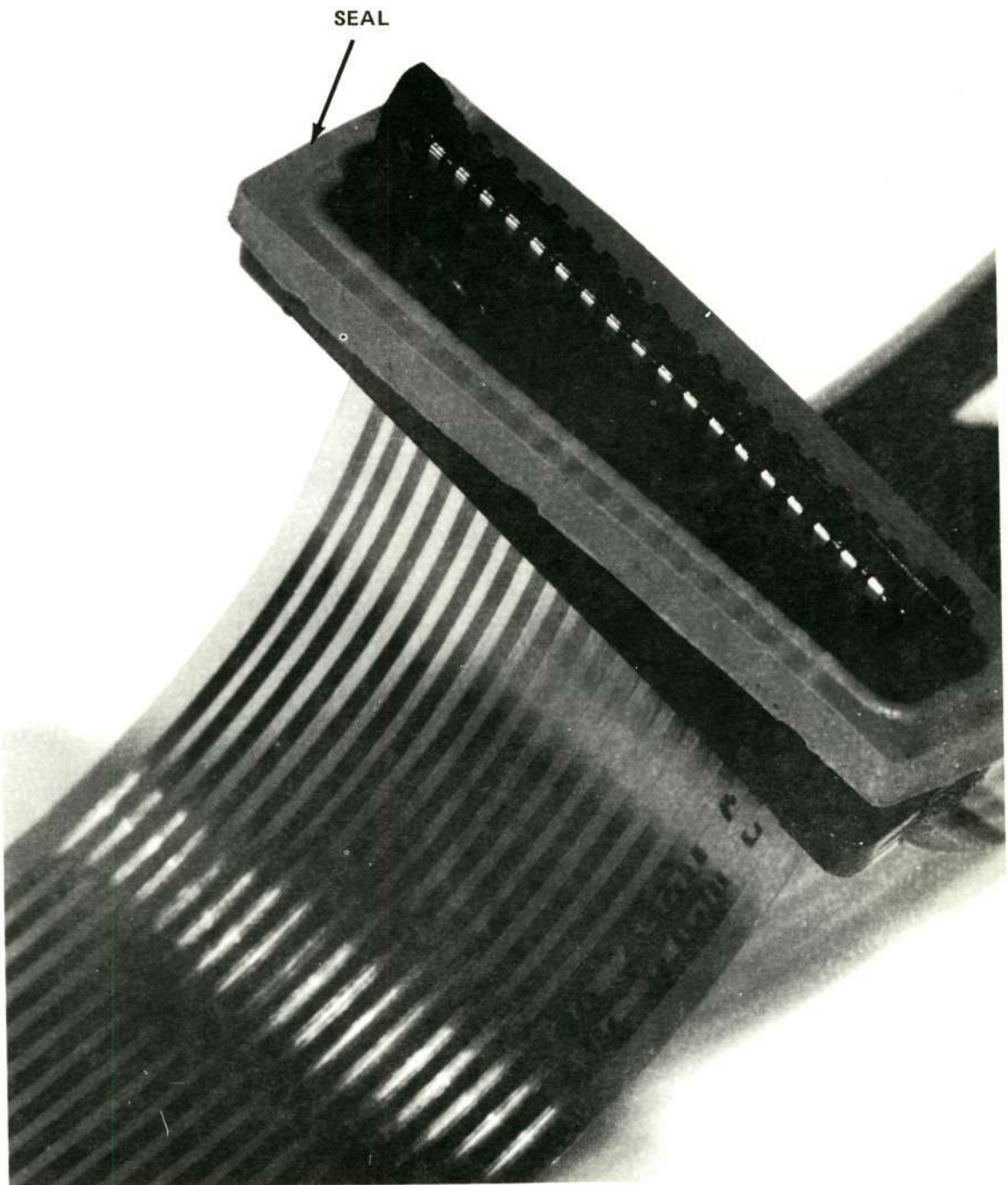


Figure 29. Pressing the peripheral seal in place.

**SECTION IV. TERMINATION OF FCC TO CYLINDRICAL
MOLDED-ON PLUG (50M72606 AND 50M72607)**

36

PLUG DESCRIPTION

The cylindrical plug (50M72606 & 50M72607) which is molded onto the FCC (Fig. 30) is one of four FCC plugs developed and used by NASA/MSFC. It is very similar to the rectangular molded-on plug; however, it is cylindrical in shape and can only be used with small flat cable widths. Designed to meet or exceed MIL-C-55544, this plug mates with several receptacles (50M72629, 50M72630, 50M72602, 50M72603) for FCC to flat (FCC or PC board) and FCC to round wire connections.

PARTS

Most of the parts of this plug are basically the same as those of the rectangular molded-on plug. These similar parts are window piece, conductor spacer, insulator, outer seal, and molded portion. In addition, the cylindrical plug has a shell and a coupling ring.

SIZES

Two sizes of plugs are available for cable widths of 0.64 cm and 1.30 cm (0.25 and 0.50 in.). These plugs will accommodate 2 flat conductor cables, containing a total of 6 or 12 conductor-contacts. The contacts measure 1 x 0.1 mm (0.04 x 0.004 in.) and are spaced on 1.9 mm (0.075 in.) centers.

CABLE AND SHIELD TERMINATION, OPERATION PARAMETERS

The method of cable and shield termination and the plug's operation parameters are the same as described earlier under "Fabrication of Rectangular Molded-On Plug."

ASSEMBLY TIME

Based on an assembly study in which FCC was terminated to twenty 3.8 cm (1.5 in.) rectangular plugs using only hand tools, total assembly time required for termination of two unshielded cables to one plug is about 10 man-minutes. This includes all plug assembly steps beginning with cutting of the two cables. If stripped conductors do not need to be plated, assembly time is reduced to 7 man-minutes. On a mass production level, total assembly time would be further reduced.

SECTION DESCRIPTION

The remainder of this section is devoted to a step-by-step presentation of the method of terminating cables and shields to a cylindrical molded-on plug and assembly of the plug.

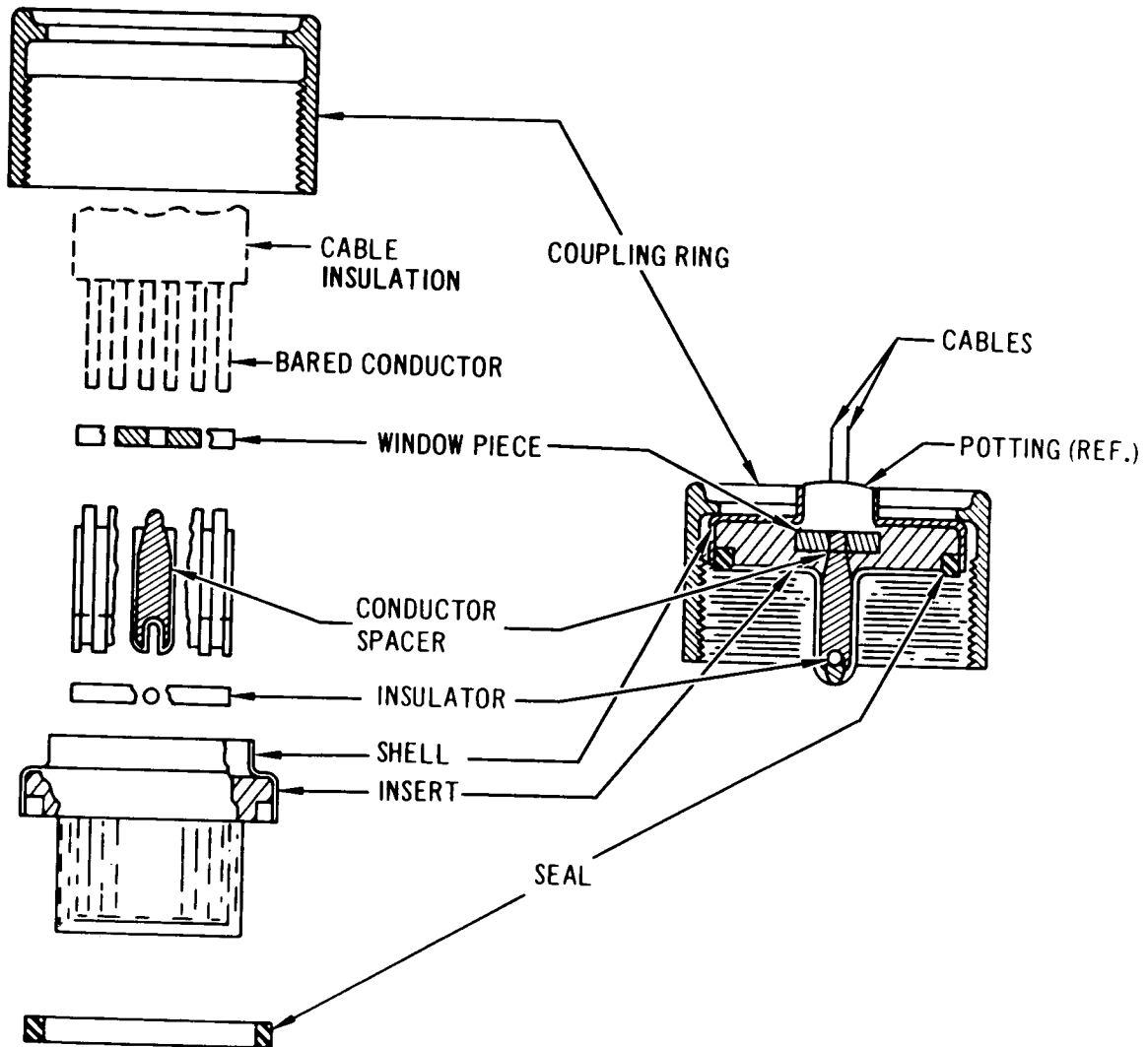


Figure 30. Cylindrical molded-on plug.

PARTS ASSEMBLY

The following steps are taken to assemble the parts.

- Two cables, with ends stripped to a length of 1.2 cm (0.47 in.), are threaded through the rear of the coupling ring and small opening of the shell (Fig. 31).
- Window piece and conductor spacer are assembled, conductors folded, and insulator installed as described for the rectangular molded-on plug. Refer to the section on that plug for information and depictions.

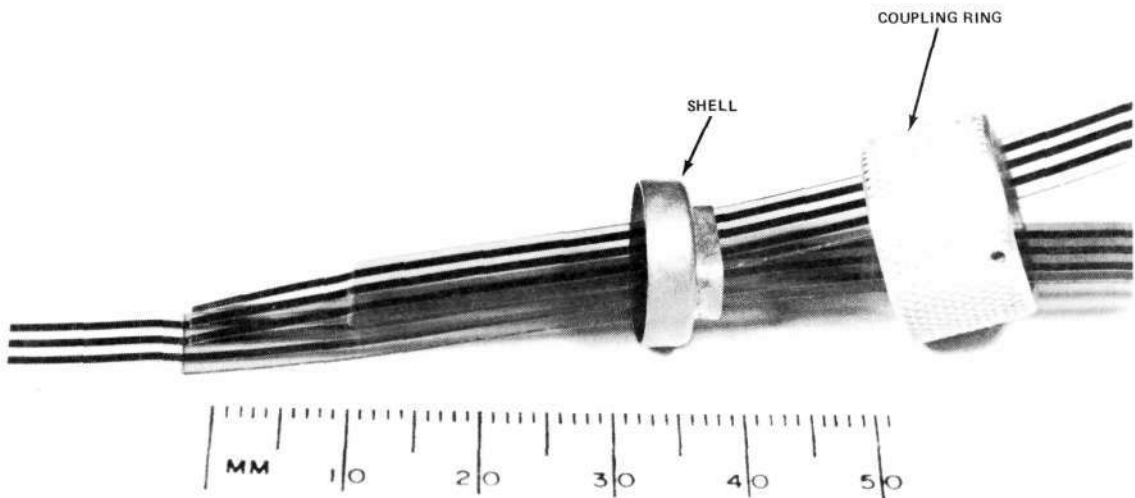


Figure 31. Threading cables through coupling ring and shell.

INJECTION MOLDING OF THE PLUG BODY

The molding of the plug body and trimming of the sprue are performed in the same manner as described and depicted in the section on the rectangular molded-on plug. However, the resulting plug body (Fig. 32) has a cylindrically shaped base rather than rectangular and does not have sufficient space for potting. Potting is accomplished after placement of the shell, which has a cavity for that purpose.

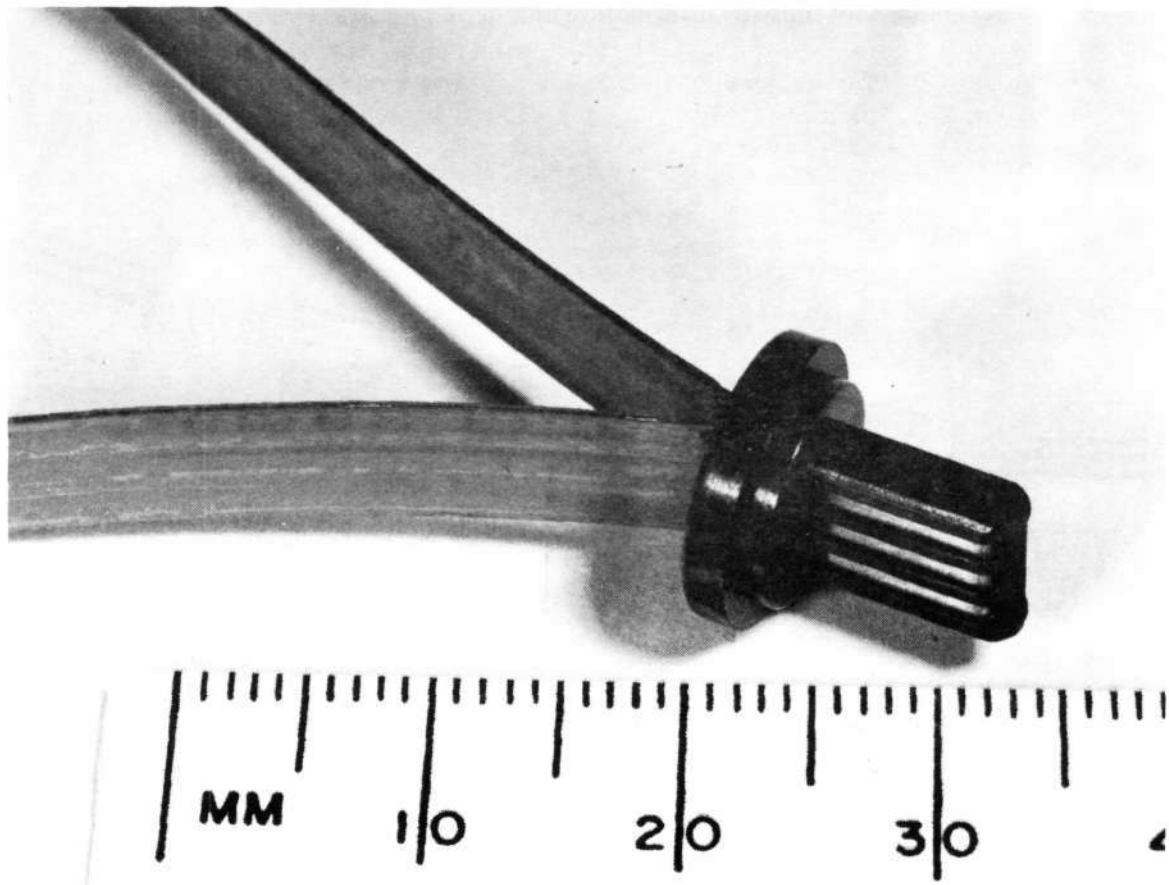


Figure 32. Molded-on plug body.

PLUG FINISHING

The following procedure is used to finish the plug.

- The shell is moved onto the body (Fig. 33), and both are dimpled with a spring-loaded punch, keeping the shell on the molded body (Fig. 34).
- Polyurethane potting compound PRC 1535 (or equivalent) is applied around and between the cables at the rear of the plug and cured for 8 hours at 60°C (140°F).
- Adhesive (Dow Corning No. 40 cement or equivalent) is applied to the step around the plug body and the seal is seated in the groove formed by the plug step and the shell, as shown in Figure 35.
- The coupling ring is moved onto the shell (Fig. 36).

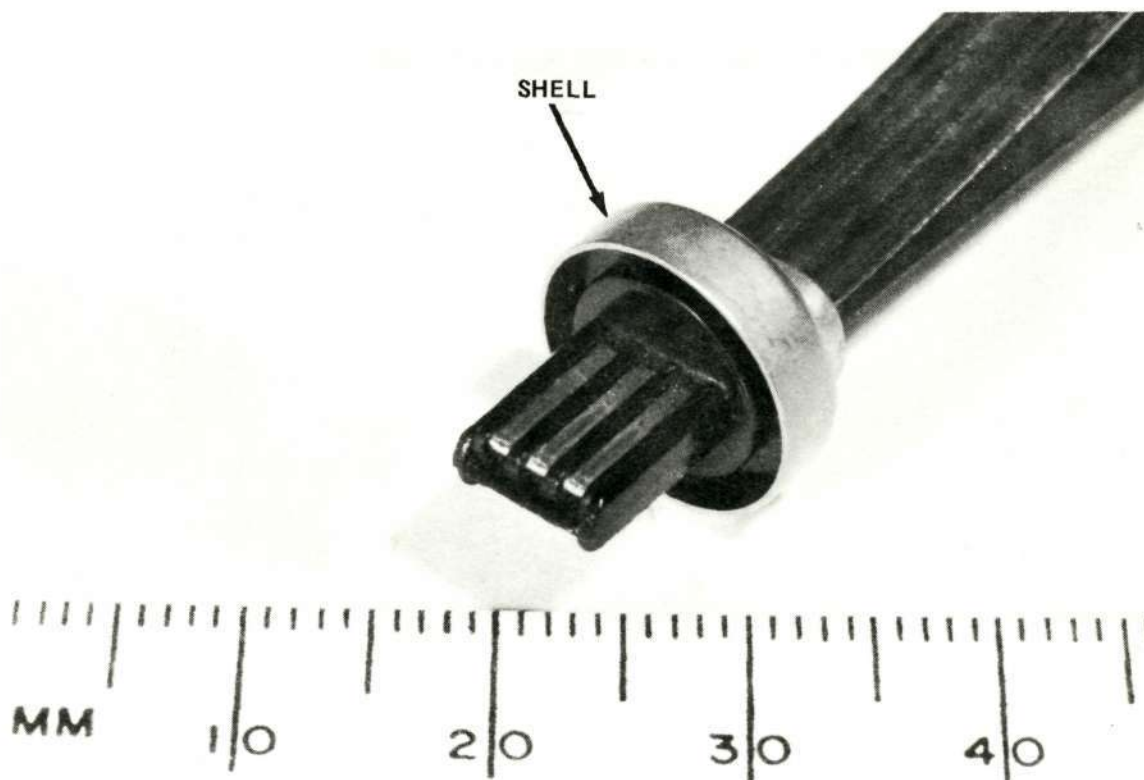


Figure 33. Shell moved in place.

**TERMINATION OF FCC TO CYLINDRICAL
MOLDED-ON PLUG (50M72606 AND 50M72607)**

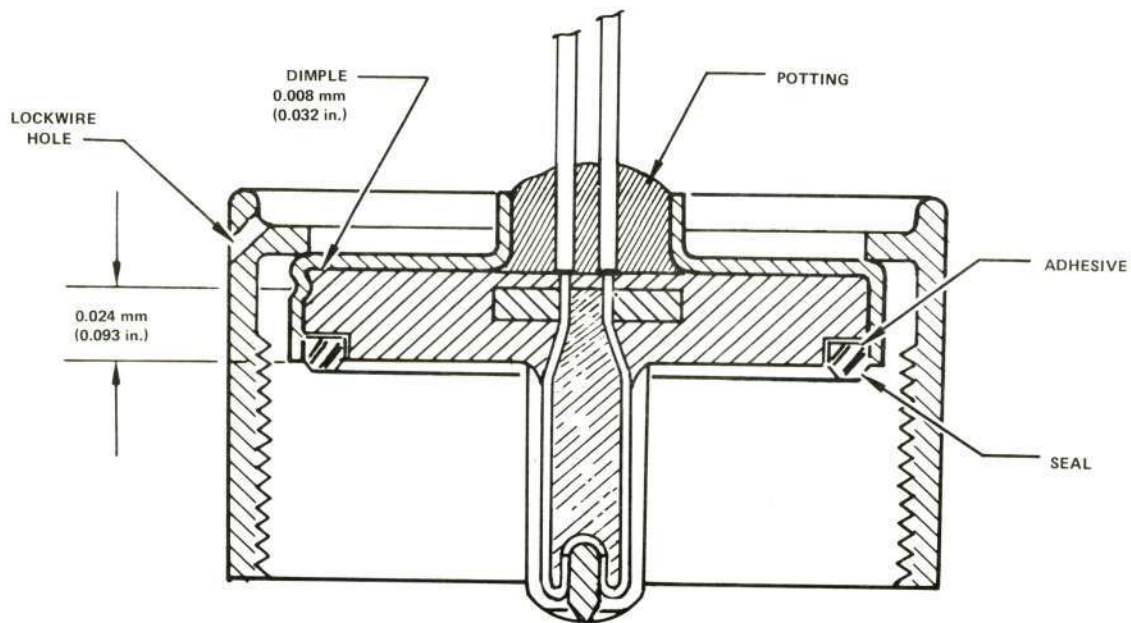


Figure 34. Shell and plug body with dimples (section).

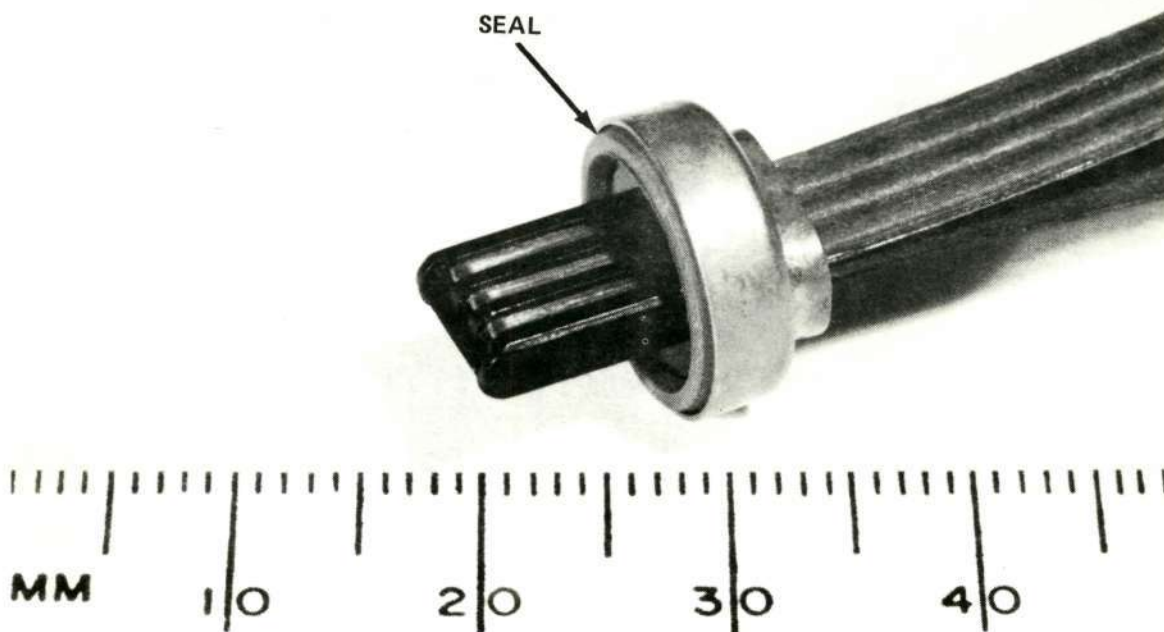
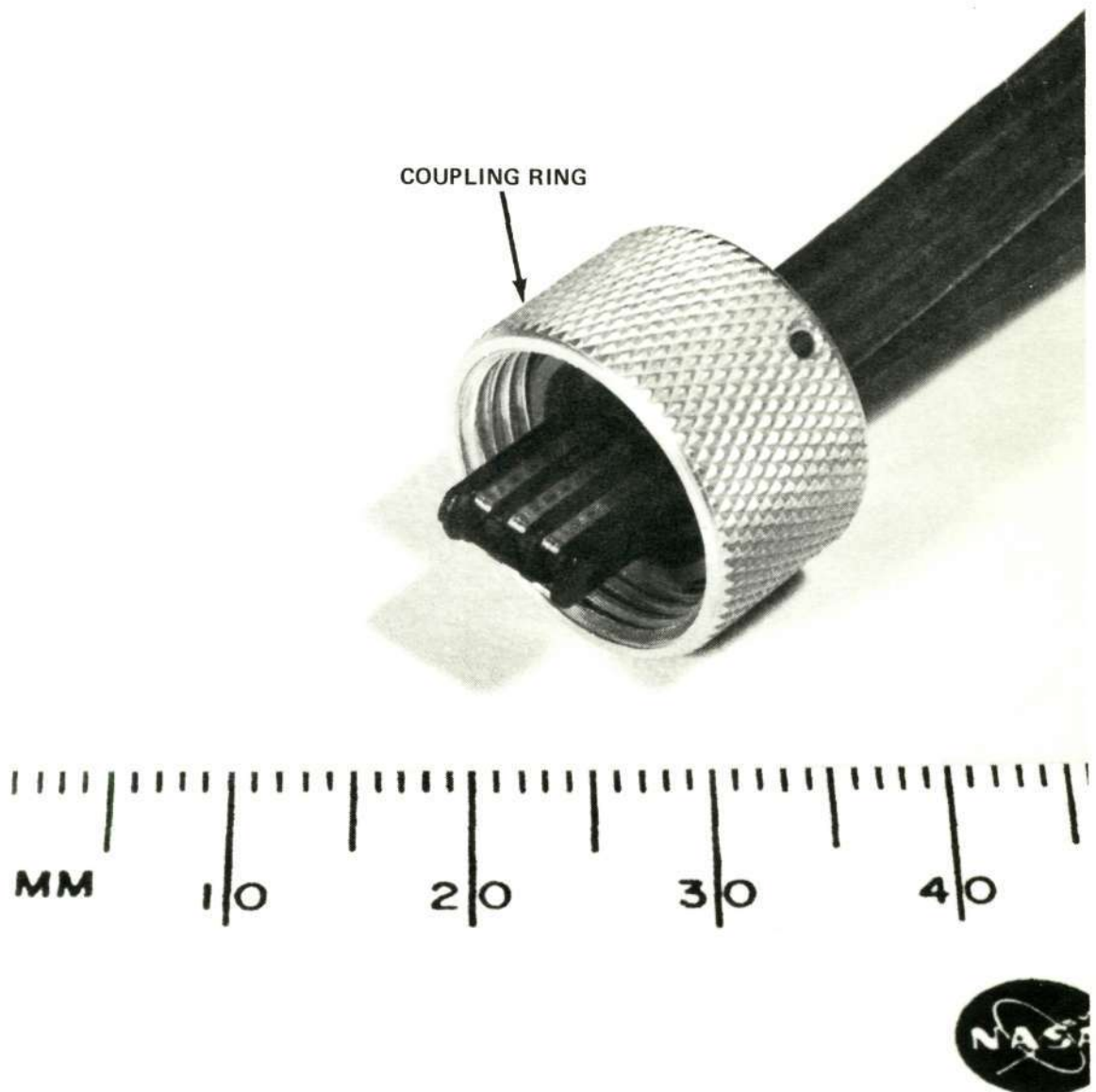


Figure 35. Peripheral seal pressed in place.



1

Figure 36. Coupling ring moved onto shell.

SECTION V. TERMINATION OF FCC TO PREMOLDED PLUG
(50M72637)

46

PLUG DESCRIPTION

GENERAL

The premolded plug (50M72637), one of four FCC plugs developed and used by NASA/MSFC, is basically the same as the rectangular molded-on plug described earlier. The major difference is that all parts of the premolded plug are fabricated prior to plug assembly. No molding-on operation is performed. Designed to meet or exceed MIL-C-55544, this plug mates with receptacles 50M72600, 95M20000, and 50M72646 for FCC to flat (FCC or PC board) and FCC to round wire connections. The plug is shown in Figures 37 and 38.

The plug size data, basic method of terminating cable conductors and shields, and operating conditions described under "Rectangular Molded-On Plug" also apply to the premolded plug. However, when an epoxy potting is used, the premolded plug can be operated at temperatures as high as 200°C (392°F).

PARTS

The plug, in addition to potting, consists of:

1. Base plate, through which the uninsulated conductors are threaded;
2. Conductor spacer, which separates conductors of one cable from the other and anchors the conductor-contacts;
3. Wedge to hold the conductor-contacts in place;
4. Housing to accommodate all parts and provide polarity keys;
5. Locking keys to lock all plug parts together; and
6. Peripheral environmental seal.

ASSEMBLY TIME

Based on an assembly study in which FCC was terminated to twenty 3.8 cm (1.5 in.) plugs using only hand tools, total assembly time required for termination of two unshielded cables to one plug is about 10 man-minutes. This includes all steps beginning with cutting of the two cables. If stripped conductors do not need to be plated, assembly time is reduced to 7 man-minutes. On a mass production level, assembly time would be further reduced.

SECTION DESCRIPTION

The remainder of this section is devoted to a step-by-step presentation of the method of terminating cables and shields to a premolded plug and assembly of the plug.

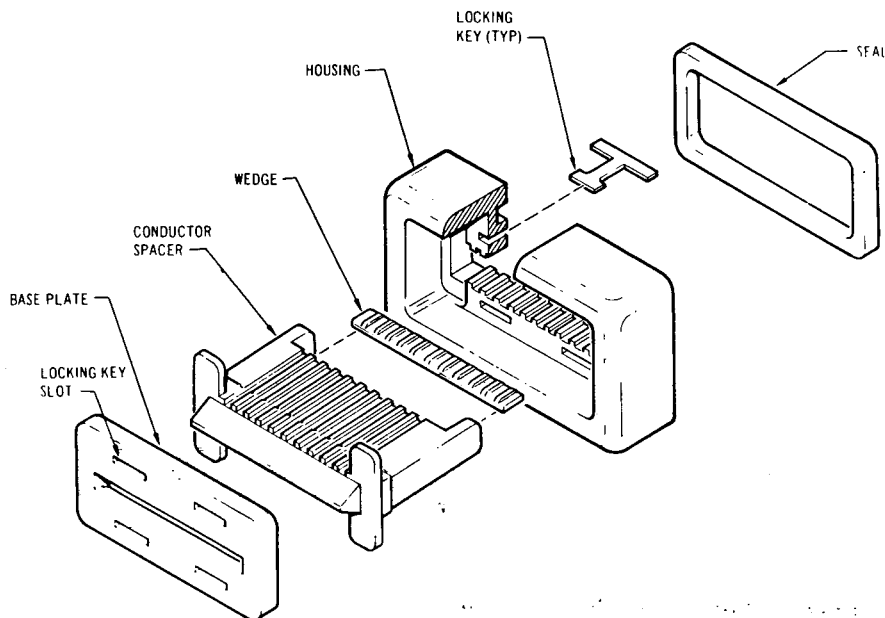


Figure 37. Exploded view of premolded plug.

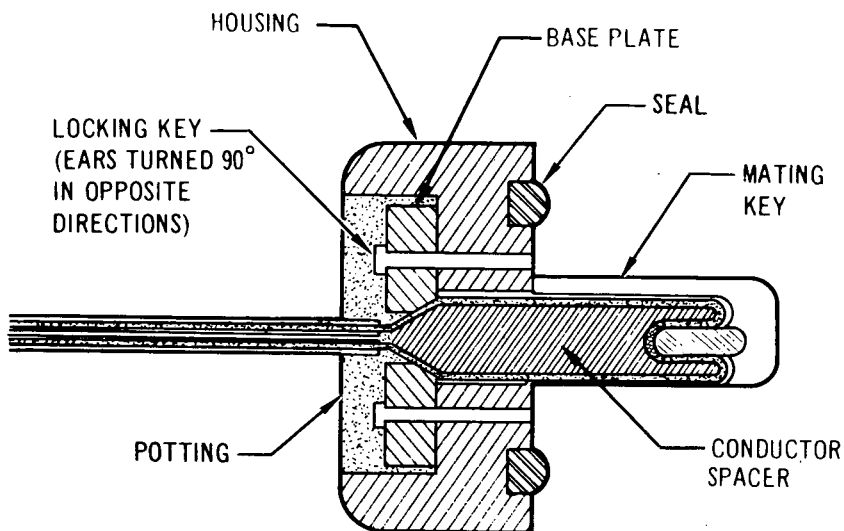


Figure 38. Premolded plug (section).

ASSEMBLY OF BASE PLATE, CONDUCTOR SPACER, AND WEDGE

Assembly of the base plate, conductor spacer, and wedge of the premolded plug is similar to assembly of the molded-on plug's window piece, spacer, and insulator. Conductors are threaded through the plate, positioned on either side of the spacer, and folded into the spacer center groove. Unlike installation of the molded-on plug's insulator (which is merely pressed in place prior to molding on the plug housing), the premolded plug's wedge must be glued in the spacer center groove to assure conductor retention.

- Conductors, stripped to a length of 1.3 cm (0.50 in.), of two cables are inserted through the center opening of the base plate, as shown in Figure 39.
- The conductor spacer is positioned between conductors of one cable and conductors of the other cable.
- The conductor spacer assembly is placed in the folding tool (a fixture similar to the molded-on plug folding tool).
 - It is inserted and fastened in the holding clamp (Fig. 40).
 - The holding clamp is positioned in the folding tool.
- Conductor folding operations are the same as performed in fabricating the molded-on plugs. Conductors of one cable are bent at a right angle and then into the spacer center groove. These operations are repeated for the other cable.
- Adhesive is applied to the wedge and the wedge is seated in the spacer groove.
- The assembly is removed from the folding tool.

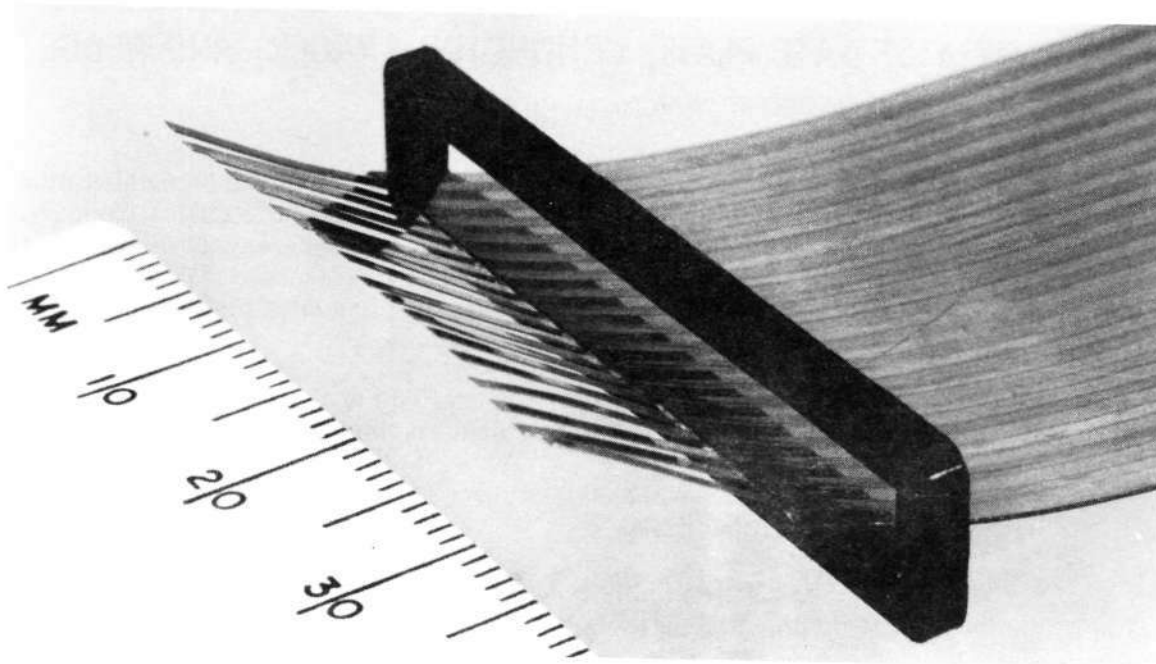


Figure 39. Inserting conductors through center opening of the base plate (only one cable shown).

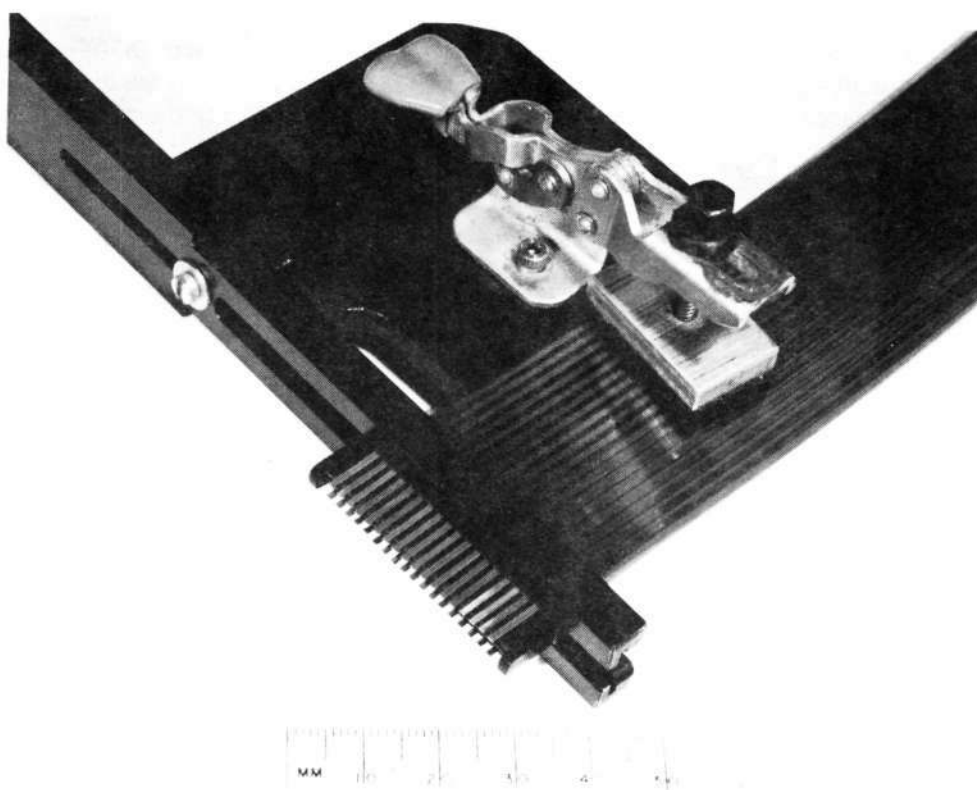


Figure 40. Conductor spacer assembly in holding clamp.

FINAL ASSEMBLY (HOUSING, LOCKING KEYS, POTTING, OUTER SEAL)

The following steps are used for final assembly.

- The conductor spacer assembly is positioned in the plug housing.
- The base plate is moved in place and pressed into the back of the housing.
- Twist locking keys are dropped in the provided slots in the housing (Fig. 41) and through the base plate. On the base plate side, key tabs are bent toward the outside of the body to lock all parts together. In Figure 42, key tabs of one of the keys have been bent in place.
- Potting is applied around and between cables at the rear of the plug and is then cured.
 - If the plug has a high temperature requirement of 200°C (392°F), epoxy compound Emerson Cummings 2651 (with catalyst #9 or #11) is used, or its equivalent. The epoxy compound with catalyst #9 is then cured for 8 hours at room temperature or for 1 hour at 71 to 77°C (160 to 170°F). The epoxy compound with catalyst #11 is cured for 3 hours at 99 to 104°C (210 to 220°F).
 - If the maximum temperature requirement is only 125°C (257°F) polyurethane PRC 1535 (or the equivalent) is used as the potting. After application, it is cured for 8 hours at 60°C (140°F).
- Adhesive (Dow Corning No. 40 cement, or equivalent) is applied to the seal groove of the plug housing, and the seal is seated into the groove.

**TERMINATION OF FCC TO
PREMOLDED PLUG (50M72637)**

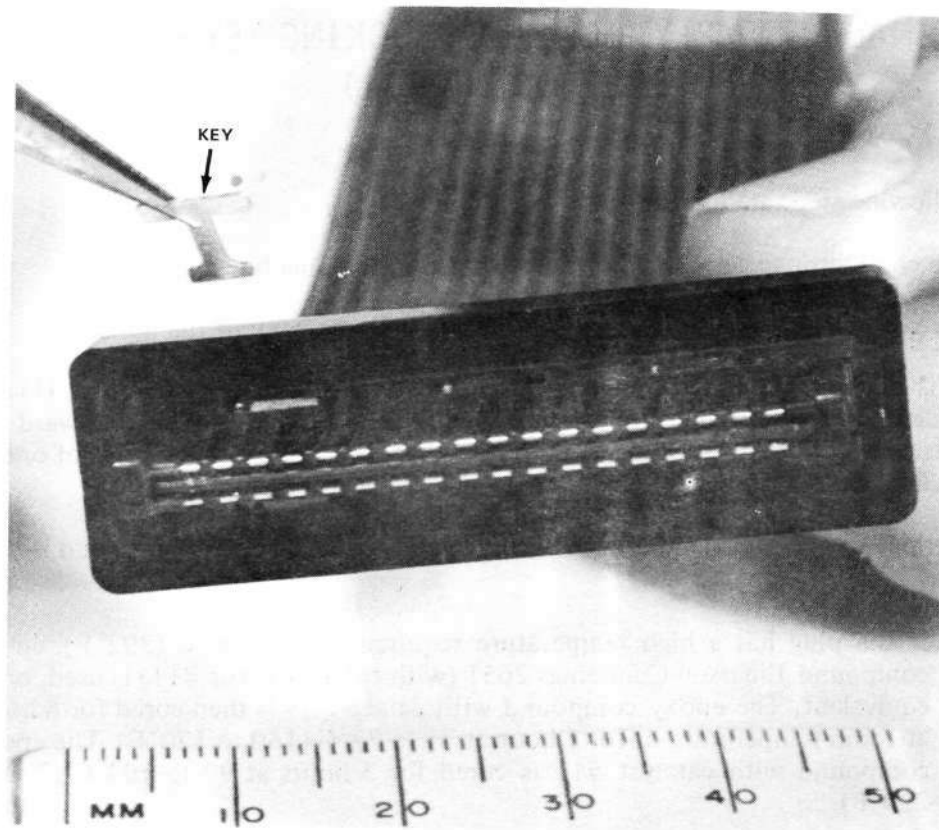


Figure 41. Dropping twist locking keys in housing slots.

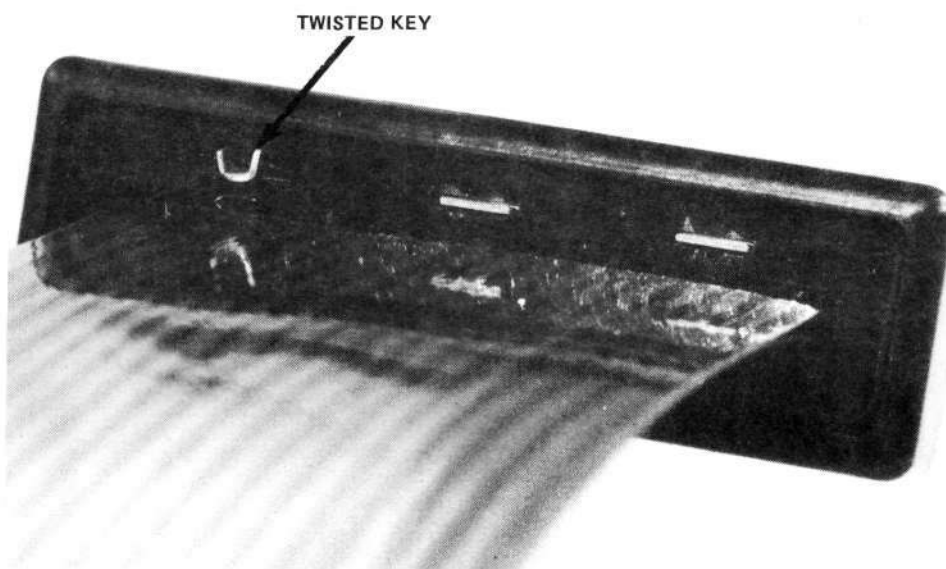


Figure 42. Twisting keys in place.

**SECTION VI. TERMINATION OF FCC TO PLUG WITH
INDIVIDUALLY SEALED CONTACTS (MR&Tsk-1556)**

55

PLUG DESCRIPTION

GENERAL

This plug (MR&Tsk-1556), shown in Figure 43, is a member of NASA/MSFC's latest family of FCC connectors. Its construction differs from that of the previously described plugs in several significant ways. First, other than potting, the plug consists of only one premolded part, into which stripped cable conductors are folded to form contacts. In addition, each folded conductor-contact is enclosed in its own housing, which is sealed off from other contact housings when the connector is mated. The resulting mated configuration provides complete corona safety at critically low gas pressures. Designed to meet or exceed MIL-C-55544, the plug mates with three receptacles (MR&Tsk-15395, MR&Tsk-15375, MR&Tsk-15424) for FCC to round wire, FCC to FCC, and FCC to PC board connections.

SIZES

The five sizes of plugs available are the same sizes noted for the rectangular molded-on and premolded plugs.

OPERATING PARAMETERS

The plug is designed for operation at 300 volts rms and 3 amperes of current per contact. The mated plug-receptacle assembly has a wear-life of at least 500 insertions. Plugs are capable of continuous operation over a temperature range of -65 to +200°C (-85 to +392°F).

CABLE AND SHIELD TERMINATION

The concept of using cable conductors as plug contact surfaces, noted for all previously described plugs, has also been applied to the design of this latest plug. However, the actual method of folding conductors (and shields terminated to the outer conductors) to form contacts is not the same, as will be demonstrated later in this section. Two methods of terminating cables to the plug are under development, one by MSFC and one by Astro-Space Laboratories, Inc. (under contract to MSFC). Principal steps in MSFC's method of cable termination are shown in Figure 44. Astro-Space's method consists of the same steps; however, the potting is performed prior to the folding operations.

ASSEMBLY TIME

Based on an assembly study in which FCC was terminated to twenty 3.8 cm (1.5 in.) plugs using only hand tools, total assembly time required for termination of two unshielded cables to one plug is about 7.5 man-minutes. This includes all plug assembly steps, beginning with cutting of the two cables. If stripped conductors do not need to be plated, assembly time is reduced to 4.5 man-minutes. On a mass production level, total assembly time would be further reduced.

SECTION DESCRIPTION

The remainder of this section is devoted to a step-by-step presentation of MSFC's method of terminating cables and shields to the plug. Also included (under the heading "Folding the Conductors") is a brief description of Astro-Space's method along with a photo of a folding tool prototype.

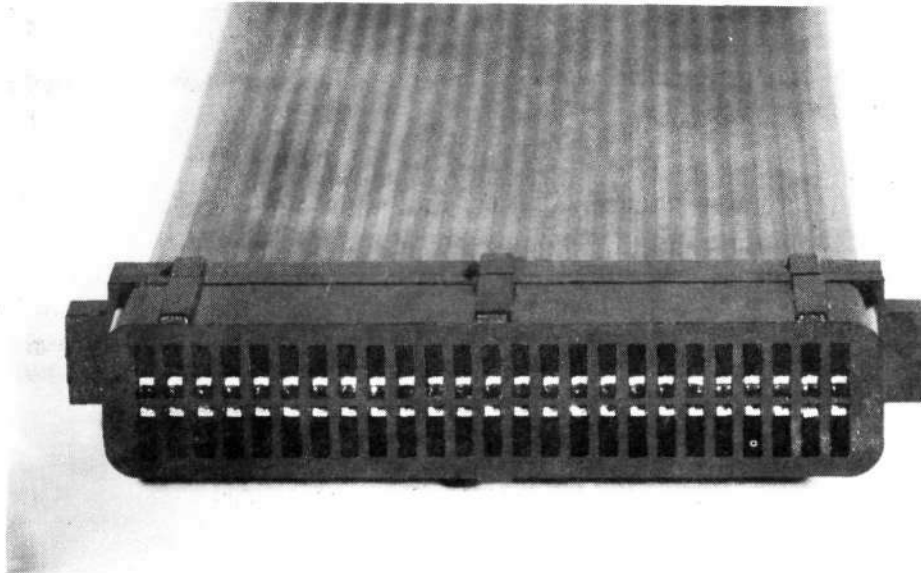


Figure 43. New MSFC plug with contacts in separate enclosures.

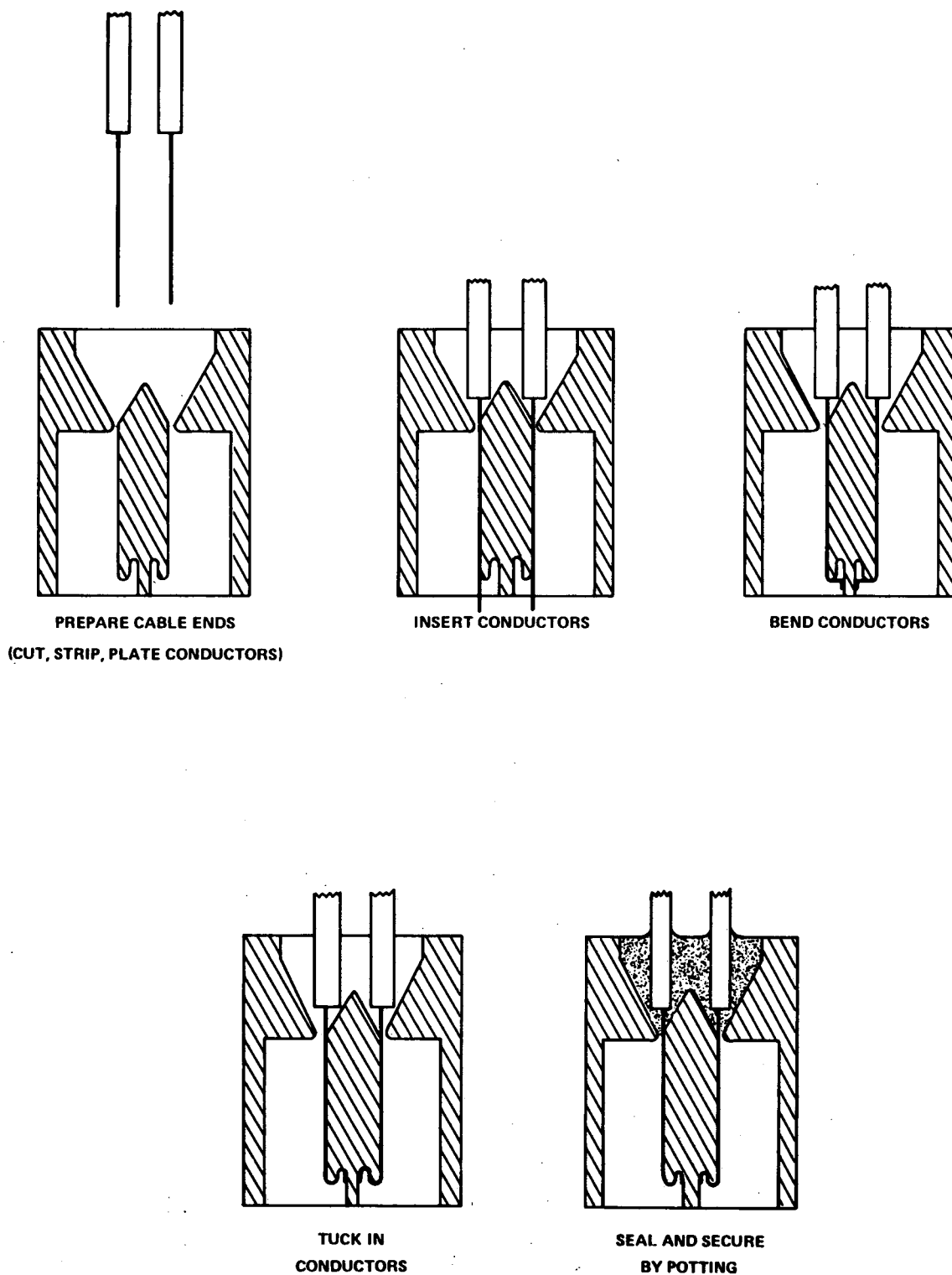


Figure 44. Steps in terminating FCC to the new MSFC plug.

THREADING CONDUCTORS THROUGH PLUG WINDOWS

Conductors, stripped to a length of about 1.0 cm (0.4 in.), of two cables are threaded through the back of the plug body (Fig. 45). The plug is designed for ease of cable insertion by providing a tapered channel for each conductor.

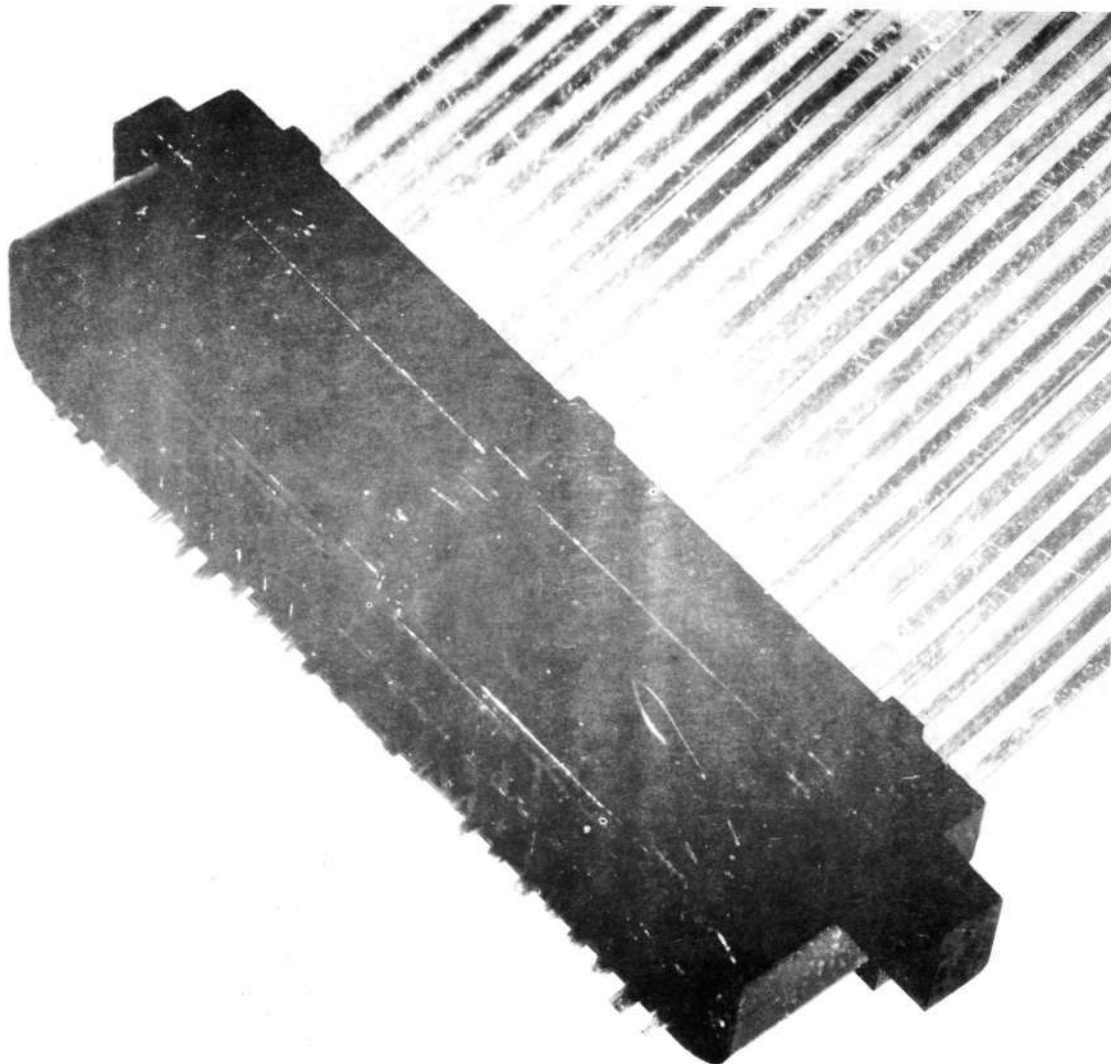


Figure 45. Threading conductors through the new plug
(only one cable shown).

CONDUCTOR ALIGNMENT

The following steps are used to align the conductors.

- The plug body assembly is inserted in a face-up position in the folding tool and placed against a stop.
- The inserted plug body is clamped in place, with cables extending out below the body on either side of a separator, an extension of the folding tool.
- Conductors of the two cables are aligned approximately, and each cable is separately clamped. These separate clamps prevent one cable from falling out while the other is being accurately aligned.
- Conductors of one cable are precisely aligned.
 - A stepped conductor gauge is placed on the plug face to cover one row of windows. In Figure 46, a prototype of the gauge part of the folding tool is being placed by hand on one row of windows.
 - One cable is unclamped, and its conductors are pushed up even with the gauge.
 - The loose cable with aligned conductors is then reclamped.
- Accurate conductor alignment using the stepped gauge is performed on the other cable.

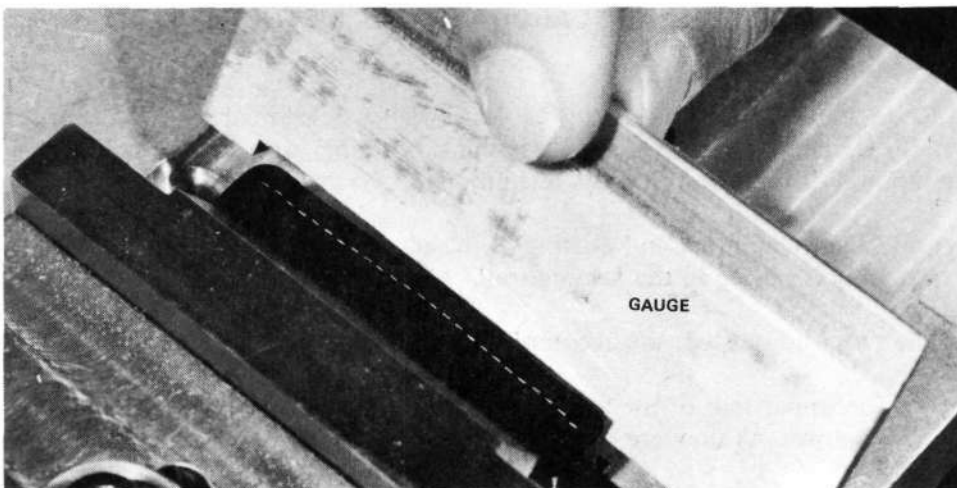


Figure 46. Placing the alignment gauge on one row of plug windows (prototype).

FOLDING THE CONDUCTORS

MSFC'S METHOD

The following is MSFC's method for folding conductors.

- The stripped conductors of both cables are pushed toward the plug's center piece, using a hand tool.
- One horizontal folding tool arm is moved so as to place a row of teeth in the windows on one side of the plug body. Each tooth firmly clamps a conductor against the plug's center piece.
- A series of sliding teeth on top of the clamping teeth are moved forward. Each sliding tooth bends a conductor into a center cavity, partially forming a contact (Fig. 44).
- The above clamping and folding steps are repeated for conductors of the other cable.
- Sliding teeth are retracted.
- A second vertical folding arm with two rows of teeth is pulled downward, placing teeth in all contact housings, and completing the folding process (Fig. 44). In this one operation, all conductors of both cables are tucked into the contact cavities, forming the contacts.

ASTRO-SPACE LABORATORIES' METHOD

A second method of terminating cables is being developed by Astro-Space, under contract to MSFC. This procedure uses a pneumatic folding tool, shown in Figure 47. The termination method differs from MSFC's technique in two major ways.

- Conductor alignment and potting of the plug back are performed before the plug assembly is placed in the folding tool.
- The two folding steps are accomplished using one vertical arm.
 - The upper half of the folding fixture is lowered, placing teeth in all plug face windows. As they are lowered, these teeth make the first conductor fold.
 - The retractable center of the vertical arm is extended, tucking the conductors in the windows, thereby forming the contacts.

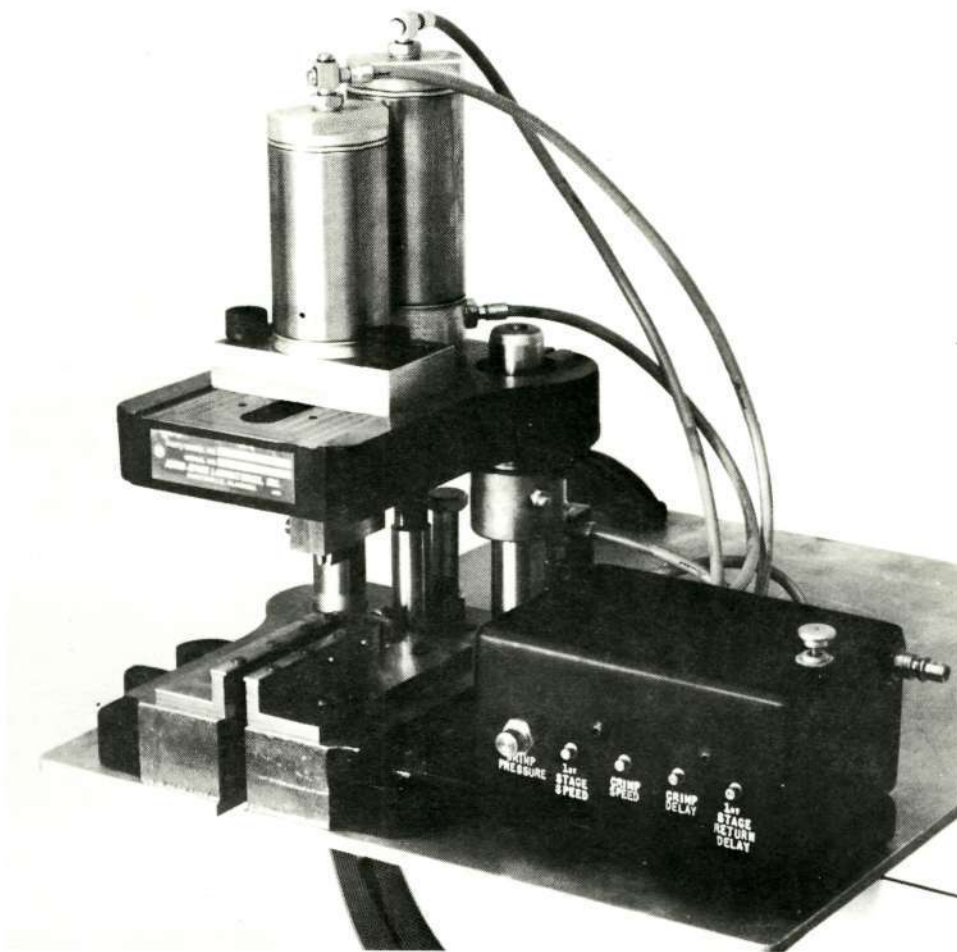


Figure 47. Prototype of pneumatic folding tool developed by Astro-Space Labs. (Folding fixture and plug-retaining fixture are removable parts which can be varied to accommodate different plug sizes.)

POTTING

The following procedure is used for potting.

- Two toothed fixtures are inserted in the windows of the plug face, one for each row of windows. These fixtures close the passages through the plug body, and thus prevent contact contamination from potting. In Figure 48, a fixture (prototype) is being inserted.
- The plug assembly is removed from the folding tool and placed in a holding device.
- Potting, epoxy compound Emerson Cummings Stylecast 2651 or equivalent is applied to the rear of the plug, around and between cables. Recommended curing time for this compound with catalyst #9 is 8 hours at room temperature or 1 hour at 71 to 77°C (160 to 170°F). With catalyst #11, the compound is cured for 3 hours at 99 to 104°C (210 to 220°F).

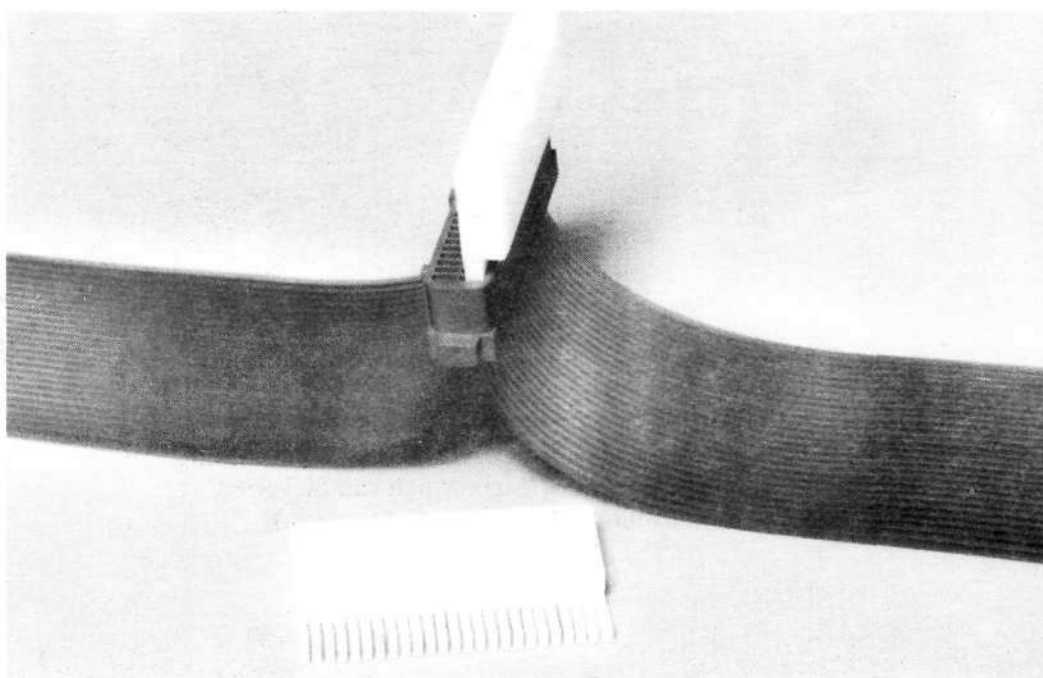


Figure 48. Inserting a potting retention fixture (prototype) in plug windows.

SECTION VII. SUMMARY AND CLOSING REMARKS

The termination hardware, tooling, procedure, and measured assembly time have been presented for various types of MSFC flat conductor cable plugs. MSFC's new plug with individually sealed contacts provides several advantages over earlier types. This multicavity plug has better protection against contamination, higher voltage ratings, complete corona protection, and requires less assembly time.

Average assembly time for the new plug as compared to earlier single cavity models is shown below. These times are the results of a timed small production effort (20 plug assemblies) in which all work was done by hand using only bench tools. For high production quantities, automatic tooling could be used, reducing the piece time drastically. However, even on a handwork basis, the average FCC termination time of 7.5 or 4.5 minutes is still significantly lower than the production time for the average round wire termination, which is well over an hour.

	Assembly Time – Minutes (2 Cables)	
	With Plating	Without Plating
Single Cavity Plug	10	7
Multicavity Plug	7.5	4.5

The new plug has additional desirable features, relative to production. The design lends itself well to automation, to easily-maintained standards of high quality, and to ease of quality control inspections. A consideration of these traits in conjunction with the low assembly time and the increased range of connector uses demonstrates the spectacular advance in design and technology of the direct-contact method of termination.

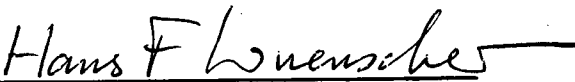
APPROVAL

TERMINATION OF FLAT CONDUCTOR CABLE TO NASA/MSFC PLUGS

By W. Angele

The information in this report has been reviewed for security classification. Review of any information concerning Department of Defense or Atomic Energy Commission programs has been made by the MSFC Security Classification Officer. This report, in its entirety, has been determined to be unclassified.

This document has also been reviewed and approved for technical accuracy.


for M. P. L. SIEBEL
Director, Process Engineering Laboratory